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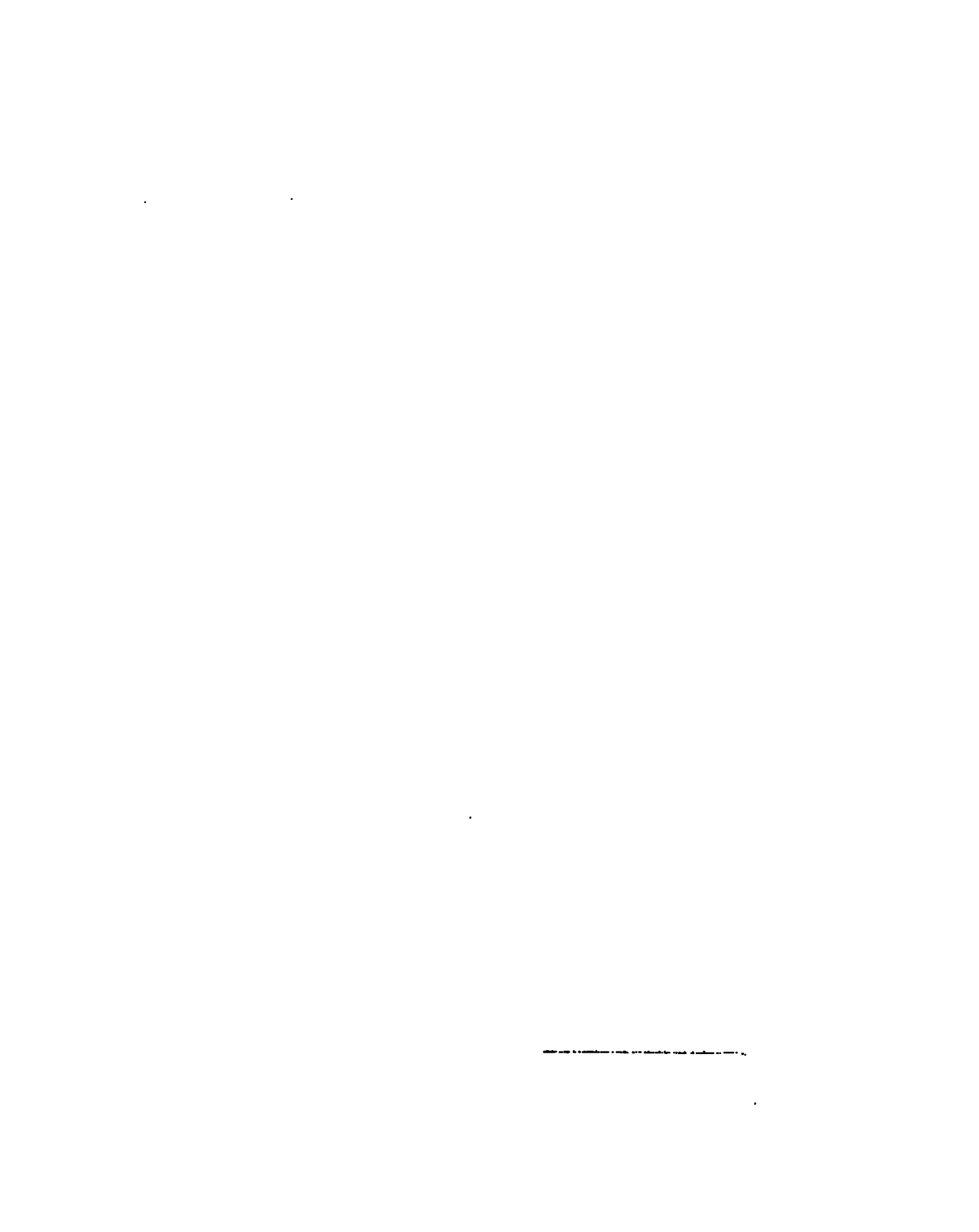
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LATHE-WORK.

L A T H E - W O R K

A PRACTICAL TREATISE

ON

THE TOOLS, APPLIANCES, AND PROCESSES EMPLOYED IN

THE ART OF TURNING

INCLUDING

HAND-TURNING, BORING AND DRILLING, THE USE OF SLIDE-
RESTS AND OVERHEAD GEAR, SCREW-CUTTING BY HAND
AND SELF-ACTING MOTION, WHEEL-CUTTING,
ETC., ETC.

BY

PAUL N. HASLUCK

With Numerous Illustrations Drawn by the Author



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1881

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PREFACE.

WHEN first I occupied myself in mechanical manipulations and lathe-work engrossed my attention, the want of a handy guide-book, treating the subject in a practical manner, was greatly felt. Though much has been done since then towards placing technical education within the reach of all, yet I recently found, in my official capacity as editor of a journal largely devoted to mechanics, that beginners at the lathe still continue to seek such a book, and I have therefore prepared the following pages.

In the form of desultory articles, written by me, much of the information has already appeared in various technical papers. The whole has been re-written for publication in book form, and it has been my endeavour to bring within the available space the information most useful to the beginner at lathe-work.

Though I make no claim to special literary merit, yet I believe that the instructions are made clear without verbiage; and as I write from personal experience, the book may be accepted as

trustworthy and practical by those who study its contents.

The illustrations have been engraved from my own drawings, and show, at a glance, constructive details that could not be explained in letterpress. The drawings are from the objects they represent, and will convey much useful information, and working drawings of the full size can be made from the woodcuts; the measurements can be filled in from the text.

P. N. HASLUCK.

LONDON, *February*, 1881.

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LATHE-WORK.

CHAPTER I.

THE ART OF TURNING.

Its importance and antiquity—Primitive methods of turning—The potter's wheel—Early forms of the lathe—Its development—Lathes on standards—Fly-wheels—Literature of the art—Modern lathes.

OF all the mechanical arts none can claim a more important place than that of turning, and the practice of this branch of mechanical manipulation is capable of developing the highest skill and intelligence of the artificer. The lathe, which has been dubbed the father of mechanism, has claimed the close attention of statesmen and philosophers; even monarchs have sought recreation in the practice of turning. Skilled artisans, who depend largely on the lathe for the production of their work, enjoy to an extent a superior position in their sphere of life, whether they be engaged in fashioning the rough wares made on the potter's wheel, or the highest and most refined specimens of turnery, which are probably to be found in the

finest grades of chronometric art. We disregard those extraordinary productions of skill and taste which come from the hands of the amateur turner, who uses for the production of a fragile gewgaw tools and appliances that only affluence can afford.

The date of the origin of turning is lost in antiquity. Probably long before historians began to write, the lathe—in a primitive form—was known and used, the potter's wheel being, perhaps, the primogenitor. The savage's process of kindling fire by twirling a stick against another piece of wood gives the motion now used for the alternating drill, and for small lathes driven with a drill bow; how this motion developed into the continuous one of the potter's wheel we can but surmise. The symmetrical cylinder is to be found throughout nature, and art in its desire to reproduce the admirable form has developed the turning lathe.

The Bible affords a distinct reference to the potter's wheel; we read that about five hundred years before the Christian era Jeremiah went down to the potter's house, "and behold he was doing a work on the wheel, making a vessel of clay with his hands." The use of the lathe, however, dates long prior to this, and the manufacture of pottery ware is frequently spoken of in sacred history. Amongst the relics of antiquity unearthed from the buried Egyptian cities are numerous specimens bearing unmistakable evidence of having been wrought in the lathe.

The lathe used by the Orientals for generations

consisted of two short posts driven into the ground ; a nail driven through each formed the centres on which the work revolved, actuated by a drill-bow. The work was thus only a few inches from the ground, and the operator in his accustomed position—squatting on the ground—was able to use his toes in assisting the application of the tools. The Orientals use the toes as deftly as they do the fingers in many of their handicrafts. At the Paris Exhibition of 1867 a group of aborigines were working in this manner with the lathe just described, displaying considerable skill in using these primitive appliances, and producing work of intricate and elaborate patterns, chiefly ornamental.

Lathes of this primitive form it would appear are employed at the present time by the native turners of India. The skill of the Hindoos in the mechanical arts and in the delicate fashioning of ivory and metal is universally appreciated, and that they should succeed so well with such rude tools is a proof of their natural aptitude. The turner of India carries on his vocation in the style of our itinerant tinker ; he carries all his tools, lathe included, about with him, and when he gets a job establishes himself near the door of his employer's house. Assisted by his boy, the turner fixes up his lathe, consisting of two posts driven into the ground, as described previously. The work is mounted between the centres, a rope is passed twice round it, and the boy, by pulling each end of the rope alternately, gives motion to the work, the workman

guiding the edge of his tool with his toes only, the handle being held by the hands at some distance from the work, both man and boy invariably squatting on the ground, as is the national custom.

Many nations in all parts of the globe employ a lathe somewhat resembling, but still an improvement on, the one just mentioned. This lathe has a frame so that it is complete in itself, yet it has to be fixed to the ground for use; it consists of two cross pieces held together by a tie-bar on which they slide, and may be wedged as required. The cross pieces have iron spikes fitted to them to form centres, the work is put between these, and they are fixed by wedging on the tie-bar. The lathe is laid on the ground and secured by means of a few spikes, a straight bar of wood is laid across the cross pieces as near as convenient to the work, and forms a rest for the turning tools. This form of lathe is still largely used in Spain, Egypt, and other places; the pattern can be traced back to the Moors, who introduced the lathe to Spain. The Spaniards in migrating took with them the lathe and the art of turning, and thus in those parts of the American continent that Spain has populated the lathe is found made as last described.

The continuous motion of the fly-wheel, which had been employed by the potter from the earliest times, was not used in the lathes of the ancients, who only had the alternating revolutionary motion derived from the bow. When introduced into the

workshops of the Western nations, the lathe was modified to suit their customs, and whilst the Orientals kept their turning appliances low, to suit their habitual squatting position, Europeans mounted the same contrivance on a framework to bring it to a convenient height to work at when standing. This altered arrangement allowed the bow worked by hand to be replaced by a flexible pole fixed overhead, from which a cord descended, and after passing round the work it joined a treadle, which was worked by the foot; then both hands were at liberty to manipulate the tools.

A picture published in a German book in the year 1568 shows a turner working a sphere in a lathe; a quantity of turned objects are lying on the bench and about the workshop. This illustration seems to be the first record of the lathe mounted on standards, and we see by it that the pole lathe was in use at that date. In books of about the same period different kinds of lathes are mentioned, but the cord up to this time appears to have been used round the work itself, which always had to run between centres. It is difficult to decide precisely when the independent mandrel came into use.

The first book devoted to the art of the turner was published at Lyons in 1701; it was written by Plumier, and probably did much for the art by placing before its votaries a record of the condition that it was then in. That there was a demand for this ponderous book appears evident from the fact of a second edition having been published in Paris

forty-eight years afterwards ; in the interim nothing was done to enrich the literature of the turner.

Bergeron's valuable book, consisting of three volumes lavishly illustrated, and containing a vast deal of information, valuable even at the present day, was next published in 1792, nearly a century after Plumier's first edition. Bergeron himself was a manufacturer of lathes and other tools used by turners, and probably in writing his book he was partially influenced by commercial considerations outside of the book itself. However, some of the information there given is equally applicable to tools now used in some cases in improved forms. The improvements made in many appliances connected with turnery since Bergeron's time, however, place his book at a disadvantage, some of the arrangements admirably sketched by him being now obsolete. Soon after this other Frenchmen wrote books on turning, the most notable being those of MM. Pauline Desormeaux and Dessables.

Holtzapffel's treatise on mechanical manipulation, which was intended to be comprised in six volumes, the first of which appeared in 1847, is the most important work on the lathe in the English language, and its value is universally acknowledged. Three volumes only were published during the lifetime of the author, and it was thought that the remaining three would never be issued. The fourth volume has, however, recently appeared as a posthumous work, and the other two may yet see light. The price of this work places it beyond the reach of the

majority of mechanics, a circumstance much to be regretted.

The modern lathe in its various forms, from the tiny tool used by the watchmaker, worked with a slip of whalebone for a bow and a horsehair for a cord, on which he fashions with a graver pivots of correct proportion and precise form on axes that are themselves sometimes less than one-hundredth of an inch in diameter and weigh but a grain, to the leviathan machine, itself weighing sometimes upwards of 60 tons, and large enough to take in work of 20 to 30 feet in diameter, and double that length, is, therefore, the result of continuous improvements, from at least the time of Jeremiah, nearly 2,500 years ago.

The employment of cast iron as a constructive material for lathes at once gave a great impetus to machinery of all kinds. The planing machine used for iron, itself an outgrowth of the lathe, did for flat surfaces what had already been done on cylindrical work, and it is to the judicious use of the lathe and the application of its modified functions that the present degree of accuracy has been attained in the manufacture of every grade of machinery.

CHAPTER II.

THE FOOT LATHE DESCRIBED.

Its various forms and sizes—Watchmaker's lathes—Bench lathes—Iron beds of various forms—Back-gearing—Slow motion—Screw-cutting motion—The lathe best suited for general purposes—The framework, bed, and fly-wheel—Mandrel headstock—Back-centre headstock—The hand-rest and collar-plate—Testing a lathe.

THE foot lathe is the tool to which we confine ourselves throughout this treatise, as it is by far the most generally adopted, though in factories where heavy work is done and steam power available the foot lathe generally is superseded by a similar tool driven by steam. The ordinary form of foot lathe is too well known to need minute description. Speaking roughly, it may be said to consist of a bed, supported at a convenient distance from the ground, carrying the headstocks. Beneath the bed a fly-wheel is fixed to revolve freely, and to the cranked axis of this wheel a treadle is attached. The motive power consists of the muscular force of the leg applied to the treadle each time that this falls on the revolution of the fly-wheel, the weight of this wheel being sufficient to cause it to revolve by its own momentum during the time when power cannot be applied through the treadle. A

band from the fly-wheel to the mandrel conveys the motion, and in this simple contrivance are the elements of a foot lathe.

The size of a lathe is described by the height of its centres—that is, the distance from the centre of the mandrel to the top of the bed. In other words, the height of centre is just half the diameter of the largest circle that will revolve in the lathe, thus the face-plate is usually a safe guide to the size of a lathe. The length of bed has much to do with the bulk, and to a certain extent with the capabilities of a lathe; for, though increasing the length of bed does not increase the capacity of a given lathe so far as diameter is concerned, yet the length of work which may be wrought on it is increased usually by about the amount of the added length. The length of bed decides the length of material that can be turned, whilst the height of centre governs the diameter; thus, a lathe on which discs of 40 inches diameter can be turned with ease is often incapable of receiving a cylinder of even 6 inches in length, and the lathes used for turning shafting, perhaps 40 feet long, are commonly not more than 6 inch centre.

Lathes over 6 inch centre are seldom driven by foot power, the exertion being too great for one man who has also to manipulate the tools. From a commercial point of view it is found to be more economical to employ steam power rather than an assistant to help tread the lathe. This latter expedient is a common practice in small

workshops where mechanical power is not available. The heavier lathes of 6 inch centre are also generally driven by steam, but some very light ones used by wood turners are driven by the foot, even though they are 7 or 8 inch centre. The hand-driven fly-wheel is generally used as the source of motion by those wood turners who do not employ steam power.

The smallest lathe is that used by watchmakers; motion is given to the work by means of a bow, the lathe is held in the jaws of the bench vice when in use. The clockmakers' throw is rather larger; it is driven by a hand-wheel, and has always dead centres; a small pulley on the left headstock, having a projecting pin to catch the tail of a carrier, being used to drive the work. The smallest of foot lathes has generally a bar-bed, of triangular section, and may be from 2 to 3 inch centre, and is in general arrangement similar to the throw, except that it has a revolving mandrel driven by a foot-wheel, and consequently some modifications are essential.

Bench lathe, or table lathe, is the name given to all those which, complete in themselves, fix on any bench that may be convenient. Lathes up to 4 inch centre having beds up to 3 feet in length are usually mounted on small standards about 3 or 4 inches high, and by these they may be screwed down to any bench. The fly-wheel for driving these lathes will have to be fixed beneath quite independently of the lathe bed and headstocks. Beds

of any sectional shape may be used for bench lathes, but the triangular bar is most in favour for small ones and is a most suitable form of bed. The triangle is placed with one angle uppermost, the two upper sides are wrought quite true and straight, the whole of the headstocks and fittings are adjusted to these sides, the lower face being that on which all the clamping screws take their bearings. Small screw-cutting lathes have sometimes a triangular bed cast with a groove along the lower surface, in which the leading screw lies protected from any falling dust and shavings made in turning. A peculiarity about triangular bar lathes is that the mandrel headstock is invariably made of two distinct pieces, one taking the tail-pin and the other the collar, each fixed independently on the bed. Though able to withstand considerable downward pressure, the triangular bar cannot resist torsion so well as the usual form of bed.

Lathes of 4 inch centre and upwards have generally a cast-iron bed, the top surface of which is planed to take the headstocks, &c. The most usual forms of fitting are the V and flat and the double flat. In the former the V-shaped bearer is the surface which guides the movable fittings when shifted along the bed, and in the latter the continuity of the line of centres is insured by having parallel tenons on the bottom of each piece, fitting without shake along the inner edges of the bed. Occasionally the outer edges are planed true ; the

side shake of the headstocks, &c., is prevented by strips screwed to their base and fitting the outer edges of the bed. This latter plan may offer some advantage in being easier to fit, but is not nearly so accurate as that of fitting the tenon to the inner sides. Some beds have a break or gap near the fast headstock, allowing large discs to be turned, but this is not desirable for ordinary use. The beds of lathes of this size are usually bolted to iron standards which carry the centre points on which the crank revolves, and also those on which the treadle oscillates. To prevent spreading at the base a stretcher-bar connects the standards at the back; and in some cases the front feet are similarly braced by means of a flat bar of iron lying close to the ground so as to be out of the way of the feet and the foot-board of the treadle.

Back gear is an arrangement of wheel-work by which a very slow motion is imparted to the mandrel; it usually consists of a wheel and pinion on the mandrel and a wheel and pinion on a shaft revolving parallel with the mandrel. Instead of fixing the pulley on the mandrel it is allowed to run loose with its front edge close to a toothed wheel which is keyed to the mandrel; a nut prevents the pulley getting away from this wheel. A pinion is fixed to the small end of the pulley on the mandrel, gearing into a wheel fixed to an axis, which also carries a pinion gearing into the wheel fixed to the mandrel. Thus on turning the pulley motion is conveyed to the mandrel through the

wheel-work, and by this means the speed is usually reduced to one-ninth; nine revolutions of the pulley produce but one turn of the mandrel. For ordinary purposes the back shaft is thrown out of gear; the pulley is then attached to the wheel, keyed to the mandrel, by means of a sliding bolt.

The illustration, Fig. 1, shows a horizontal section of a back-geared headstock. The mandrel runs in double bearings, and its tail-end is prolonged to form a stud, on which change-wheels for screw-cutting purposes are placed. Referring to the mandrel, and commencing at the right-hand end, first comes the nose, on which chucks are screwed, immediately behind it the shoulder, and then a conical part, forming the front bearing. Against a shoulder the wheel keyed to the mandrel is shown; the pulley and pinion solid with it revolving loose, except when attached to the wheel by the bolt arrangement. Behind the pulley is a nut, shown in section, and a washer, made of hard steel, fitted tightly to the mandrel. This washer, bearing against the collar in the casting, takes the back thrust in boring and such operations. That part of the mandrel passing through the collar is coned to form the back bearing; a washer comes next this, being secured by a nut, as shown. The end-shake of the mandrel is regulated by the adjustment of the nuts on each side of the back collar. The stud forming the tail-end has a key fixed to it, shown white in the illustration.

The back spindle is a plain steel arbor carrying

a wheel and pinion securely fixed together, and tight on the spindle. In the position shown in Fig. 1 the wheel and pinion are out of gear with those on the mandrel. A peg put into the hole in the casting (see left-hand end) prevents the back

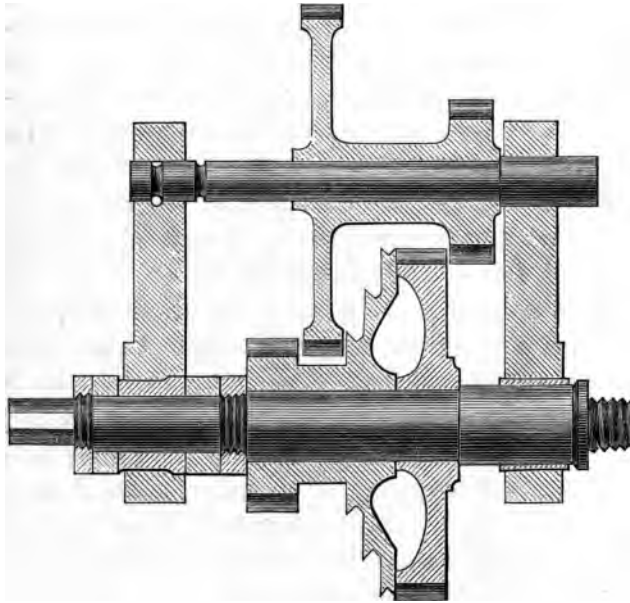


Fig. 1.—Plan Section of Back-gear, Double Bearing, Screw-cutting Mandrel Headstock.

spindle shifting and getting into gear. When it is desired to put the wheels in gear the peg is withdrawn, the spindle moved towards the left till the right side groove is under the hole. The peg is then replaced to keep the spindle in its new position. The mandrel-wheel and pulley are at

the same time disconnected to allow the gearing to act.

Though back-gearing is undoubtedly a very valuable auxiliary to a lathe on which much heavy metal turning is done, yet for most purposes an arrangement of slow-motion bands will suffice. By this means the constant noise and jarring accompanying the use of wheel-gearing is done away with. Much smoother work is produced by having a strong gut band from a small pulley on the crank shaft to a large one on the mandrel. When these two pulleys are of equal size it is possible to turn up a cast-iron face-plate of the full diameter that the lathe will take, and by putting a pulley of half the diameter on the crank-shaft such a job could be accomplished with tolerable ease. Such heavy work is, however, usually done by steam-power, and all the power that can be judiciously got out of a foot lathe is usually obtainable with simple slow-motion bands.

The slide-rest is an attachment of so much importance that an entire chapter is devoted to the description of its varieties and merits. The chief object of this—all that need here be mentioned—is to form a perfectly rigid tool-holder, which, holding the tool mechanically, does not allow the inequalities of the work to exert so much influence as is unavoidable in hand turning; moreover, guiding the tool mechanically, it does so with a precision unattainable in hand-work.

Screw-cutting lathes are those which, by an

arrangement of wheels receiving motion from the mandrel and conveying it to the leading screw, move the slide-rest along the lathe bed at a uniform rate, so that a tool fixed in the rest will cut a regular spiral on the surface of a cylinder revolving between the centres. By arranging the wheels which transmit the motion from the mandrel to the screw in relative proportions, the rate or pitch of the thread cut on the work may be coarse or fine to any degree within the compass of the wheels available; these are called change-wheels, twenty-two usually constituting the set.

The leading screw itself revolves, in bearings attached to the bed, sometimes inside but generally on the near side of the bed; the end towards the mandrel projects and is made to take the change-wheels. A slotted arm called the wheel-plate, swinging round the screw, carries one or more studs on which the change-wheels also fit, the piece of mandrel projecting at the tail-end being similarly shaped; and thus a wheel on the leading screw, another on the stud, and another on the mandrel make a combination producing an effect proportionate to their relative diameters. The slide-rest is fitted with a clutch gearing into the leading screw and forming a nut, which may be detached instantly. A screw-cutting lathe not only enables one to cut threads of any rate and diameter perfectly true, but it is also available for working as a self-acting machine when turning cylinders,

the rate of screw then being cut amounting to nothing more than a regular feed.

It is unnecessary, in this treatise, to speak of the more uncommon modifications of lathes, which fit them for special purposes and are not of general interest. The next consideration will be, What is a suitable lathe for general use?

Probably the requirements of each individual reader will have certain peculiarities which it is quite impossible to take into consideration when treating of the subject in a general manner. For small work in metal a heavy 4-inch centre lathe will be useful, whilst for working in wood a light 6-inch would be more appropriate. Brass work requires quick speeds, which are best maintained with a light lathe; but heavy iron and steel work is wrought at a slow speed on a heavy substantial tool. The exertion required to drive a 6-inch lathe will be much more than that necessary for a smaller lathe of similar calibre, and thus it is but a waste of energy to employ a lathe unnecessarily large.

For general purposes a 5-inch centre lathe will be found most handy, the height of centre allowing a wide range in diameter. Then, if the mandrel is moderately light, without back-gear it will be strong enough to take the heaviest work that can be done on a 4-inch lathe, with the advantage of offering facilities for turning wood and light material of much larger size. The bed may be 3 feet 6 inches to 4 feet long, allowing lengths of 2 feet to 2 feet

6 inches between the centre points. The convenience of the longer bed consists principally in having the poppit headstock or slide-rest out of the way when either of these is pushed to the end. With short beds it is sometimes necessary to remove the slide-rest or poppit in order to get at the work conveniently, and this is some trouble.

A heavy bed, bolted to substantial standards, is most desirable; the bed for a 5-inch should measure about 4 inches in width and depth; if a double flat the central space may be about $1\frac{1}{4}$ inch wide, leaving each flat a trifle wider. A 4-foot bed should weigh at least $\frac{3}{4}$ of a cwt. The fly-wheel of such a lathe should have series of grooves in steps corresponding with those of the mandrel pulley, so that the band may be shifted to any grooves on a series, and fit taut without any readjustment of length; there should be two series of grooves, for each a special length of band being necessary. The extreme diameter of the wheel may be 24 to 26 inches, with a series of three or four grooves graduated from the largest possible size. The second series would be about half that diameter, and have but two grooves; in cases where the suggestion before made of having a small pulley for slow motion is adopted this may be from 4 to 6 inches in diameter. Fly-wheels are generally too light; $\frac{3}{4}$ of a cwt. is not any too heavy for one 24 inches in diameter. The crank shaft should be $1\frac{1}{4}$ inch diameter, and if 4 feet long, two cranks are advisable, as they support a long treadle better than a single crank,

which is, however, quite enough for one 3 feet 6 inches long. The ends should always be plugged with hardened steel, and drilled up properly before being countersunk; the end should then be turned down conically to meet the edge of the countersink, so that when in position and running the oil applied to lubricate will not be thrown away from the centres by centrifugal force. This is an important point, though constantly neglected by lathe-makers. By observing a crank-shaft with flat ends it will be seen that the oil, applied to the centre, quickly spreads over the face and runs away from the bearing—when the crank is still, by gravity, and when revolving, by centrifugal force. The wheel is usually fixed to the shaft by keying, though sometimes it is secured against a shoulder on the shaft by means of a nut. The points on which the axis revolves should be so adjusted that though the bearing is quite free there is no shake whatever, and the position of these points must be such that the crank shaft runs parallel with the lathe bed. The wheel itself must be fixed perfectly true, and in a vertical line under the mandrel pulley.

The headstock of a plain lathe, in which the mandrel runs—called the mandrel headstock, or fast headstock, to distinguish it from the movable or poppit headstock, which takes the back centre—should have a deep tenon cast on the bottom, to make the casting rigid; the upper side should be hollowed out to allow freedom for a large pulley, which for a 5-inch lathe may be $8\frac{1}{2}$ inches in dia-

meter. The length of the mandrel adds much to the steadiness in turning, provided always that only the smallest possible amount projects from the collar at the nose end. A mandrel, 8 inches long, is a good proportion, and would be spaced thus: the thread of the nose, $\frac{3}{4}$ inch long, cut with a $\frac{3}{4}$ inch Whitworth thread; cone for front bearing, 1 inch long, the diameter being about $1\frac{1}{8}$ inch, tapering about 1° ; plain part, $1\frac{1}{4}$ inch long, $1\frac{3}{8}$ diameter; pulley, $2\frac{1}{4}$ inch; washer, nut, and plain part behind pulley 2 inches, with a small part $\frac{3}{4}$ inch long, terminating in a cone point. The headstock for such a mandrel would be 10 inches long at the base, with a portion of the boss which holds the tail-pin projecting about $\frac{1}{2}$ inch to the rear, the total length of the hole in which the tail-pin fits being fully 2 inches; the tail-pin should be cylindrical, perfectly true, and fit the hole tightly, being held by a nut on each end. Tail-pins, which are themselves screwed through the casting and fixed with a lock nut should be invariably avoided, as with such the countersunk hole, bored in the centre, is sure to be eccentric when turned in the thread, and thus the axial line of the mandrel would be continually altered. That the headstock casting fits the bed properly is most essential; in many cases it will be found that the casting gets bent on the holding-down bolt being screwed tight, thus throwing the boring of the collar-hole and the tail-pin hole out of continuity. A direct pull by one bolt, near the centre, so often bends the casting that it is

advisable to hold it down by two bolts, one near each end.

The back centre headstock should always be bored out quite parallel and in a direct line with the axis of the mandrel, the barrel being cylindrical, with a groove along it in which a T-headed blank screw, dropped into a hole in the casting, fits and prevents the barrel rotating. The screw which actuates the barrel is usually made with a left-handed thread, for convenience in turning, but whether left or right handed is perfectly immaterial, except for the convenience. For turning the screw a hand wheel or a winch handle is used; the former is more convenient for boring with, and the latter offers the advantage of not being so much in the way. An arrangement for clamping the barrel at any desired place always forms part of the poppit head, and if a screw acting direct on to the cylinder is used, a disc of brass or other soft metal should be interposed to save the barrel from being dented. The point of the poppit cylinder is always removable; sometimes it is fitted by screwing into the barrel; but another and far better plan is to fit it in conically. The cone fitting is as tight as any—in fact some lathes have conical noses, on which the chucks fit by simply pressing on, and they then jamb. A cone fitting to the back centre offers great facility for shifting the point, an operation which sometimes has to be done constantly. The screw inside the poppit barrel should be sufficiently long to allow the tail end of the point to be made long enough to touch when the

barrel is drawn back, and thus the point is forced out by simply winding back the cylinder. Several points should be fitted to the back centre, and some pieces with flat ends for boring against; these are, however, spoken of in another chapter. The diameter of the barrel may be an inch, the cylindrical part of the casting into which it fits being about $1\frac{1}{4}$ inch in diameter. The barrel is bored out from the front end large enough to clear the thread of the screw by which it is moved, to within half an inch or so of the back end; this part is tapped to fit the screw. The lateral motion of the screw is confined by having a collar on it, which on one side bears against a loose washer resting against the end of the casting, and on the other against the cap screwed on to the casting. The handle on the end of the screw should not confine its lateral motion, and it is often merely pushed on a square or hexagonal fitting, though sometimes secured by a key or a nut.

The hand or T-rest needs but little comment; the socket should be bored at right angles to the sole, which should be planed with a dovetailed slot. If the lathe bed is double flat the sole of the hand-rest stands direct on it; if a V-bed it should have a cast-iron foundation plate, shaped to fit the bed on the under side and flat on the top. The screw which clamps the T should have a handle like that of a bench vice fitted to it, as it so often requires to be shifted to suit the work in hand. A "permanent tommy" is also desirable in the screw

which clamps the back centre barrel, as it is so much more handy to be able to fix these parts without the trouble of finding the "tommy" on each occasion.

The T itself for general use may be about 2 inches long on the top and should be flat and level ; in use it will be continually pitted, and must be filed up smooth again. For turning long cylinders by hand a much longer T is used, measuring as much as 5 or 6 inches. For still longer rods it is customary to use a straight bar as a rest, which is supported near its ends in two T socket-holders ; by this plan a rest, reaching the entire length of the bed between the centres, can easily be fitted up. In turning work of short length the T-rest is sometimes found to be in the way, and a 7-rest is used instead ; this is made of an angle piece, one leg fitted to the rest socket, and the other filed flat on that surface forming the top. The 7-rest is often used with the point towards the work, thus giving a rest of about $\frac{3}{4}$ of an inch in length, very convenient for short work. T and 7 rests are usually made of cast iron, but wrought iron is sometimes used, and this is the better material, especially for the latter shape.

A collar-plate is an arrangement in general use for supporting the ends of rods whilst these are being bored up ; it consists of a disc of cast iron having a quantity of holes bored near its edge. These holes are very much coned and are graduated in size ; in use the largest side is put towards the mandrel, and the bar being turned revolves in the

conical hole as in a collar. The plate is fixed by its centre by means of a bolt clamping it against a dwarf casting. The work before being put in the collar-plate has its end turned true, and the extreme edge rounded off to prevent its cutting the plate, a drop of oil being applied to lubricate the bearing. The axial continuity of the work is preserved by placing the back centre against it before finally adjusting and fixing the collar-plate, which is screwed tight at such a position that the work turns freely without shake. On removing the poppit head the centre of the end of the bar may be operated upon as required ; it may be bored up with a drill and the hole then enlarged and made true with a tool in the slide-rest, or otherwise treated.

The chief essential requisites of a good lathe are that the bed should be sufficiently strong to be quite rigid, and that the headstocks fit it properly at all parts of its length; this latter may be tested by trying them. A bed "in winding" is an abomination, though sometimes to be met with, being the result of careless chucking in the planing machine; through bad bolting to the standards a bed is sometimes thrown "in winding." For this defect test with winding strips, which are perfectly parallel straight edges, by placing them transversely across the bed at various places, and noticing that the top edges of both are level. The entire framework of the under part of the lathe should be strong and firmly braced together standing on four feet, each touching the floor, so that solidity is

imparted to the whole structure. The treadle should be as low as possible, just to be clear of the floor when at its lowest point, rising to about 9 or 10 inches. A narrow strip of wood nailed to the floor just in front of the foot-board of the treadle will serve as a guard to prevent the toes from getting underneath.

That the entire line of centres should be perfectly parallel with the bed is always desirable, and in many cases absolutely essential for producing true work. The two ends of the mandrel should be exactly equidistant from the bed, as should be both ends of the poppit cylinder. The effect of having the axis of rotation of the mandrel at an angle with the bed is not shown when turning between centres, though the carrier and the pin of the driver-chuck will be continually rubbing against each other to an extent proportionate to the error in the line of centres. The mandrel may be differently distanced from the bed at one end than at the other, without affecting the work between centres, though when chucked without any back support the free end of the work will be more or less above, below, or on one side of the back centre point, as work unsupported will naturally take the position of an axial continuity of the mandrel itself.

In order to test the truth of the axis of rotation with the lathe bed itself, the positions of the mandrel bearings must be gauged. The parallelism of these bearings with the top and inside of

the bed will be shown by fixing, in a chuck, a bar of metal as long as possible, to allow the back centre to stand on the bed with the point clear. This bar of metal must be centred whilst running in the lathe, and its centre will, if the mandrel is parallel with the bed, coincide with the point of the poppit; the bar must be strong enough to bear its own weight without drooping at the unsupported end, or the test will show false. Another method of testing the whole of the holes in the headstocks is by putting the mandrel head to the right of the poppit, and reversing the barrel so that it protrudes at its right-hand end; then if the point of the poppit comes exactly opposite the tail-pin of the mandrel, or its centre if in double bearings, the continuity of the axial line of centres is proved to be in a straight line with the bed.

Another good plan, perhaps the better, is to fit a hard wood mandrel in the bearings, leaving at each end, projecting a few inches from the casting, a cylindrical portion of exactly the same diameter. Make a template or gauge of sheet metal to show the distance of these portions from the bed, and gauge carefully at both ends; any error will be at once felt, as the sense of touch is marvellously keen. This is proved by the ease with which minute differences, that cannot be detected by the eye, are discovered by the feel in callipering. Unless a good light is on the object it is difficult to see minute errors.

A perfect fit of the mandrel bearings may be

proved by screwing the tail-pin as tight as possible, so that the mandrel may be turned by hand, and if there are no places where the fit is easier than at others you may consider it accurate, providing that there is no side shake whatever. The mandrel must always be kept up to its bearing by the tail-pin, and never allowed to run loose, or the bearings will be worn unequally.

The flange of the nose, against which the chucks screw, ought to be quite flat and perfectly true, so should the thread of the nose, though it is rather the exception to find that it is so. Some makers turn a groove in the mandrel at the back of the thread, reducing the diameter to that at the bottom of the thread, though with what reason is not easily conceivable. The effect is to very materially weaken the mandrel at that part which is, under the most favourable circumstances, its weakest place. The bearing of the mandrel should be of steel and very hard, and the face against which the chucks jamb should also be of steel—in fact, a continuation of the bearing, the usual plan being to shrink a steel collar on a mandrel of fagoted iron.

If the boring of the poppit headstock is anything but absolutely true with the line of centres, the position of the back centre point, relative to the axial continuity of the mandrel, will be constantly varying as the poppit barrel is wound out. The truth of this boring can be tested to a certain extent by winding out the point as far as possible without allowing the barrel to become loose in the

hole, and then testing it with a point-chuck. The oppositeness of the points cannot be tested by contact with any degree of accuracy. The best plan is to use a narrow parallel straight edge and adjust the cones to that distance apart which just allows the straight edge to go between them, with its opposite edges resting against the opposite sides of the cones. The straight edge is applied on both sides, above and below, and readily shows the oppositeness of the points. The poppit may be gauged in the same way as described for testing the mandrel bearing with a wooden temporary mandrel; using the barrel, which must fit nicely, projecting at both ends of the casting.

CHAPTER III.

HAND TURNING.

First principles of the art, commencing to practise—Wood turning, the gouge and the chisel—The mode of their application to the cylinder and surface—Easily made objects for beginners—Making a plain wooden box—Metal turning, the graver and triangular tool, and their use—Finishing tools, round nose tools, &c.

WHEN commencing to practise the art of turning it is advisable to begin by using simple tools and appliances, and with them to execute work of the most rudimentary kind, so that the learner may become properly acquainted with the elements of lathe-work, and he will then be able to understand the execution of the more complicated work. It sometimes happens that a fine collection of tools comes into the hands of one who has never had any previous practice in their use, but who will nevertheless boldly essay to use the most complicated machinery before troubling to learn the principles that govern its application, and which are only to be studied in using the simpler tools. A person unacquainted with the conditions under which a hand-tool acts most favourably, only to be learned by practice, cannot correctly judge the best position in which to fix a tool in the slide-rest; and

the art of turning, like all others, to be learned properly must be begun at the beginning. The first lesson in turning should, therefore, be at a plain foot lathe with back-centre and T-rest only, all the apparatus and attachments which have been described as adapted for special purposes being removed entirely, for though the slide-rest may be very useful to assist a beginner in roughing-down the work, yet it would be most injudicious to make use of such an apparatus before acquiring a thorough mastership over hand-tools.

A plain parallel cylinder is, perhaps, the very best object for a beginner to try his hand at producing, for its simple form dispenses with all complex manipulation of the tools; yet the production of a true cylinder can only be achieved after much practice, and such work demands more skill than would be at first sight imagined. Any slight slip of the tool causing its point to dig into the work would, of course, spoil a cylinder nearly finished to a definite size; but for practice such a mishap would be of no consequence, only necessitating the reduction of the entire cylinder to the size of its smallest diameter. For wood turning the gouge and chisel are the tools most generally used, and they will be sufficient for our work; a similar cylinder of metal would be turned with a graver. Soft wood will do for material, though hard wood is more pleasant to work, and will not require driving at a high speed, which is tiring to the tyro. A chuck will be wanted to carry the

work, and the prong-chuck, described in another chapter, is best suited to the purpose; and we will suppose the rough wood mounted between such a chuck and the back-centre, which is screwed up to take firm bearing and the extreme point oiled.

For soft wood turning, place the band on the pair of grooves giving the quickest motion—that is, from the largest on the fly-wheel to the smallest on the mandrel—and in revolving the work it will be scarcely possible to drive it too quick. The hand-rest is then adjusted so that the top edge of the T is on a level with the lathe-centres, and the work revolves just clear of it. The position for standing at the lathe whilst turning a cylinder is with the shoulders fairly parallel with the lathe-bed, the body upright, resting on one foot, the other being on the foot-board of the treadle, the operator using either leg to support him, and occasionally changing from one foot to the other as he becomes tired; the foot on the ground is placed as far towards the lathe as the treadle-board will allow. With a balanced fly-wheel, that is, one weighted so that the crank always stands, when at rest, slightly inclined forward from its highest point, the treadle will be in the position to receive the pressure of the foot. Under ordinary circumstances the lathe-band is pulled down from the mandrel or the fly-wheel is revolved by the left hand, so as to bring the crank into the position described, and then pressure is exerted on the treadle, and the work revolves. Two or three strokes are given to

get up the momentum before the tool is applied to the work.

The turner's gouge is used for roughing out wood-work, and a turner should provide himself with several sizes, according to the work he has to execute. For general use a gouge half-an-inch or so wide will be found most serviceable; the tool is sharpened differently to the carpenter's gouge, so as to leave the cutting edge rounded off instead of square with the shaft of the tool, as in the carpenter's gouge. The grinding is all done from the outside of the semicircle, and forms one continuous bevel, leaving an acute angle for the cutting edge. Gouges should be fitted into long handles to enable the operator to have complete control over the tool when in use. A half-inch gouge may be a foot or so long from end to end of tool and handle combined; larger sizes are much longer, frequently measuring as much as 2 feet, and sometimes even more. The gouge is grasped firmly near the cutting end by the left hand, the knuckles being uppermost, and is laid on the rest with its curved side downwards; the right hand holds the end of the handle, and usually rests against the side of the body, to afford greater steadiness. Thus held, the edge of the gouge is gradually brought sufficiently near the revolving cylinder to touch it in the position known as at a tangent to the circle, that is, so that a line drawn in continuation of the ground bevel will touch but not cut into the cylinder. In this position the tool will not cut, but on raising the end of

the handle with the right hand the edge of the tool is depressed, and becomes in the position of a tangent to a smaller circle, then all the material outside of that diameter will be shaved off by the tool. The pressure on the edge during the process tends to force the tool deeper into the work, and, therefore, the end held in the right hand must be kept down till the work has been reduced all round to the new diameter, when the gouge will again cease to cut. A slight elevation of the handle will again throw the edge into the cylinder, and so on till enough has been removed from the work.

Though the elevation of the handle has been described as an intermittant process, yet in practice it is, of course, a continuous one, for it is by raising the handle that the tool is fed into the work, the thickness of the shaving being regulated by the feed thus given. If the theory which governs the cutting of the gouge is properly understood it will be easy to carry out the principle in practice, and thus rapidly acquire proficiency in the use of the tool. By means of the gouge the rough wood is turned to a circular form, all the angles are removed, and the work made as straight as possible. A pair of callipers is used to measure or gauge the size from end to end, and those parts found to exceed the general diameter are reduced, so that the surface will be fairly straight. There will, however, yet remain a series of ridges resulting from the use of the circular-pointed gouge, and these are

shaved off by the use of a chisel applied in a similar way.

The turner's chisel is a flat tool similar to the carpenter's paring chisel, but ground very differently. It is bevelled equally from each side, leaving the cutting edge in the centre of the thickness, at an oblique angle with the sides of the shaft, instead of square across, as in the carpenter's chisel, the angles being usually about 70° and 110° . The chisel is held in the same manner as the gouge, with the lower corner of the obtuse angle edge placed on the rest. The chisel is tilted up sufficiently to bring the central part of the cutting edge against the work, leaving both corners free, for should the entire width of the cutting edge be brought to bear on the work the tool will dig in. With the edge lying obliquely against the cylinder the chisel may be slid along the rest with the bottom edge leading, and the cut taken from either end, according to which of the two corners of the tool is laid on the rest. The principles which govern the gouge apply equally to the chisel, and by a proper amount of tilt a shaving of any desired thickness may be removed; the shavings may be so thin as to produce a barely perceptible difference in the diameter of the work. When the ridges left by the gouge have been entirely obliterated the diameter of the cylinder is tested by callipering, and any irregularity can be smoothed off with the chisel.

Capital practice for a beginner will be to take a shaving from end to end of a parallel cylinder, still

leaving it perfectly parallel after the shaving is removed. This is not difficult when the manipulation of the tool is quite under control; the thickness of the shaving will be the best guide, and this may be regulated to the greatest nicety by adjusting the height of the tool handle held in the right hand.

The directions here given for using the gouge and chisel on a plain cylinder are equally applicable for turning cones, which are similarly formed with these tools.

For turning the surface of wood chucked plankways the same tools are used, the T-rest being placed round to lie parallel with the face of the work, and the gouge held in a more horizontal position than when applied to the cylinder. The chisel is used with its broad surface resting flat on the top of the T, the whole breadth of the cutting edge against the work, but held so that the corner on the side towards which the tool is advanced barely touches; the action of the chisel being scraping rather than cutting, though shavings are produced.

It is curious that beginners at turning are often at a loss to find an object on which to practise, so that descriptions of a few that can be easily made will be suggestive of others. Ordinary round rulers, varying from 6 inches to 2 feet in length, and from $\frac{1}{2}$ inch to $1\frac{1}{4}$ inch in diameter, are of very simple form. By following the directions just given on the use of the gouge

and chisel it will be easy to turn rulers, and so gain experience. A roller on which to hang a jack-towel and a rolling-pin are usually to be found in every household, and capital practice will be afforded in turning exact copies of such things. Cricketers' stumps and bales, tool handles, trenchers, and numerous other common articles are made on the lathe. The production of these will afford variety to the practice and enlarge the range of work without very severely taxing the skill, yet always adding to the capacity of the workman. It is well to remember that an adept at turning such simple objects will find it easy to proceed to the execution of the most complicated work. A plain wooden box affords considerable practice in the use of hand-turning tools, and the method of making one is this :—Having decided on the size of the proposed box, select a piece of wood, almost any kind will do, but preferably use that which has a close even grain. See that the ends are cut tolerably square, and mark a circle on each to serve as a guide for roughing out the circumference as nearly round as possible, first with a hatchet, and afterwards with a rasp. The length of the wood must be :—the height of the box, the height of the rim on which the cover shuts, the height of the cover itself, enough space to allow the parting-tool to be used twice—that is, where the lid is separated from the body of the box, and where the box is cut from the superfluous piece in the chuck—and enough to chuck the wood by. All these measurements added

together show the length of wood required to make the box. It is important to measure the rough block to see that there is sufficient material, as it will be a great saving of labour if the complete box, lid, and body are turned from one instead of from several pieces of material.

The roughly-shaped cylindrical block has now to be chucked firmly on the lathe, it may be fixed in a cup-chuck if one of convenient size is to be found; or a boxwood chuck may be hollowed out, to a depth of about a quarter of an inch, sufficiently large in diameter to allow the wood to be driven in firmly by a few smart blows of a mallet. That end which is cut most nearly square with the cylindrical sides should be chosen for driving into the chuck. It should not be made to bottom, that is, the block should be driven into the chuck to touch all the way round. When properly chucked the end of the wood is first operated upon with the gouge and turned true; the tool is held as described in the early part of this chapter, working from the circumference towards the centre. When turned true, the chisel is used to smooth the surface and make it flat; the cylindrical surface of the cylinder is turned true in the manner previously described for such work, and the rough block is thus got to a truly cylindrical form, parallel and square at the end. So far the work has been only preparatory.

The first operation in making the box itself is to shape the lid. On the circumference of the cylinder

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mark a ring showing the depth of the intended lid—this may be done with the angle of the chisel—then hollow out the front to the required depth, to leave sufficient thickness of material at the top of the lid; a side tool will do this part of the work most easily. The rim of the lid for the box should be slightly undercut in both directions; a very little will suffice, so that it will fit closer on to the box. With a wood-parting tool the lid is cut off from the rest of the wood; the tool should cut only a narrow groove, and the direction of this must be carefully maintained so that the thickness of the lid will be equal and sufficient for due strength. Tolerable truth will suffice, as the top of the lid will be finally finished later on when it is snapped on the body part, and the top will then face the back centre. In parting off the wood the groove must be kept wide enough to allow the tool to be free of the sides. When getting near the centre extra care is necessary to guard against the tool catching in and tearing off the lid, in which case the probable result would be that the breakage would spoil the lid.

The wood now left in the chuck is to form the body of the box; it is first hollowed out to form the interior, the same tool and the same general principles as were employed in turning out the inside of the lid being applicable, the precise height having first been marked on the outside. Before removing the entire inside of the box, the neck part on which the lid fixes must be turned to fit

and the lid snapped on tightly. In turning down the neck, when it nearly approaches the required size, it is advisable to frequently try the lid on it, otherwise too much material may be removed and the job spoilt. With experience, however, it becomes easy to fit without trying the sizes more than once. There should not be the slightest play or shake in the fitting, the rim should be quite true cylindrically and the shoulder equally true flatways, so that when the lid is put on and gently forced to its place the join should be absolutely imperceptible but for the appearance of the grain of the wood. With the lid fitting tightly it can be turned up true with the chisel, comparatively light cuts will only be necessary as the work has already been made true. The cover may be slightly dome-shaped, and the side of the box should be turned with the chisel to make it and the lid perfectly coincident.

With the parting tool the box may be now partially cut off from the remaining piece of waste wood, but before being entirely detached the exterior ought to be finished. The turning chisel, if properly handled, will leave a surface that will be difficult to improve upon, but if any roughness exists it may be smoothed with fine glass-paper. The inside of the box is also finished before the parting tool finally cuts it off; the sides are made straight and the bottom flat and then the box body is cut off, the parting tool being held at a slight angle to the axis of rotation so as to slightly undercut the bottom which will then stand firmly on its edges,

and requires no further treatment. If it is desired to turn the bottom face, the piece of waste wood can be hollowed out so as to fit the rim on which the lid fits, and chucked by this the bottom may be operated upon as required, leaving it slightly concave. Every time that the box or lid is re-chucked it must run as true as it did in its former position, and to re-chuck work perfectly true is one of the first lessons that a turner should study. There are also the fittings of the lid to the box and the box to the chuck, which will be excellent practice.

It may be assumed that when a plain box, in common wood, can be turned out of hand in every respect well made, the maker has attained sufficient skill in the use of his tools to warrant his undertaking without fear of failure work of far more complicated design and apparently more difficult to execute. The plain box just described is scarcely a piece of work likely to attract the attention of those who have an extensive assortment of tools and appliances; still the care and attention which must necessarily be bestowed on the various operations incidental to its production afford an amount of practice in the use of hand tools on wood which is considerable and varied, and should be prized accordingly.

Turning metal by means of hand tools is a process in every way similar to that just described, modified to suit the nature of the material. It is generally found that an inexperienced hand succeeds better in turning metal than wood; there is,

however, no more difficulty in working this latter material, and the circumstance named is due to the more obvious effect produced with wood, making it much easier to see the effect of the tools used, but more difficult to guide them. Wood is turned at a far greater speed than is metal, and the material is much softer, so that whilst the tool more easily penetrates the work and "catches in," this is more liable to be torn than the more tenacious metal revolving at a less velocity.

The same angle is to be preserved in applying the tool to metal, that is, it should form a tangent to the circle being cut, but consequent on the hardness of the material the angles of the cutting edges must be altered to make them stronger; however, the workman who, by practice on wood, makes himself familiar with the most favourable conditions under which the tool acts, will be best able to apply tools to metal to the greatest advantage.

The graver is the most general tool for metal turning. It is a bar of square steel, usually about one-quarter to five-sixteenths of an inch in size, though smaller and larger are used. All the flats are sometimes, but two are always, ground flat and smooth. The end is ground off diagonally, those edges formed by the sides meeting at the point being used for turning. The angle made by the diagonal diamond-shaped end with the shank varies to suit the material that it is intended to act upon, from 60° to 70° being about the usual limit.

The triangular tool is also much used. It is

generally made from a worn-out triangular file, of the dimensions named as usual for gravers, and is merely ground on the faces to take out all the marks of the file teeth, leaving sharp edges at the angles, all of which are 60° . The end is ground off obliquely, leaving a point at one angle, but the tool is generally used to cut with its side edges; and in this respect it principally differs from the graver, which is used only at the end.

With the two tools named most of the rough turning by hand on metal is done. Tools for metal have short handles. In use the left hand generally grasps the T-rest and the tool, the fingers encircling the stem of the rest socket and the thumb clasping the tool to the T. The right hand holds the handle as described in holding wood-turning tools; indeed, sometimes both hands are used as there described, only closer together, a natural consequence on the reduced length of the handle and tool itself. A lubricant is used with these tools on wrought iron and steel; this is necessary to keep the edge cool and lubricate the cutting. Water answers the purpose, but soapy water is better, and perhaps quite as good as oil, though much cheaper. Cast iron, brass, and gun-metal are turned dry.

The way in which the graver is applied to the work is this:—the tool is laid with one angle on the T-rest, the point being towards the back centre, and the handle at an angle with the line of centres. The lathe being set in motion and the graver

brought as near as possible to the work, it is firmly indented on the rest, and by bringing the handle towards the right the point is made to cut the work; the operation is assisted by turning the graver slightly over towards the left. This action makes a narrow groove on the work, and when the handle is so far to the right that the tool is disengaged, the graver is shifted along the rest to recommence the same process. The work turned by this means will consist of a series of grooves, more or less irregular, but the concentric truth will be correct. In the same way the triangular tool may be used to produce a like result.

To further finish the cylinder, after it has been made as straight as can be with the graver, a flat tool is used. This somewhat resembles a carpenter's chisel ground off square at the end so that no bevel exists. This tool is applied, end on, to the cylinder, and cuts away all the ridges reducing the surface to one level. This flat tool may be from about half-an-inch wide and one-eighth thick up to double these dimensions; it can be used indifferently with either edge to cut. Cylinders with straight surfaces, whether parallel or coned, are generally finally finished by filing whilst in rapid revolution in the lathe, a fine file being used. To produce an extra smooth surface emery paper wrapped round the file is afterwards applied, and by this means a very high finish can be given to the work.

Round-nosed tools, which are made of strips of

steel of various widths and thicknesses, having the ends ground off to a semicircular shape, are used for hollowing out the exterior of metal work and turning curvilinear grooves. Tools of a similar construction with the ends shaped to various patterns are largely used for turning beadings and mouldings of various kinds. Numerous tools ground to particular forms are employed for special purposes, but of these little need be said here.

CHAPTER IV.

SCREW-CUTTING BY HAND.

Striking the thread with outside and inside comb-screw tools—Originating a thread—The method of cutting the thread in a lathe chuck minutely described.

CUTTING screws by means of comb-screw tools guided by hand is a process only to be learnt after considerable practical experience has been attained in the use of hand tools on the ordinary cylindrical work. The tools themselves are made in pairs, one for use on the external the other on the internal thread; they may be bought at all tool shops where turning tools are sold. One pair is of course only applicable to one particular rate of thread, though it may be cut on any diameter. The same screw tool that cuts a thread of, say, fifty turns to the inch on a screw one-eighth of an inch in diameter is also used if the same rate of thread is required, say 2 inches in diameter as in optical instruments. For holes of very small diameter it is very seldom that comb-screw tools are used, and if under certain sizes it is impossible. Taps are generally used for all inside threads that have a thoroughfare hole excepting in optical work; the

workmen in that trade always using comb tools to cut the fine threads. Holes which cannot be tapped, through having a bottom, may be cut with a comb tool, and the process is explained in detail, with special reference to chasing the screw inside a chuck, in the latter part of this chapter.

The outside screw tool is very much used for cutting the threads in bolts and all kinds of work that can be mounted in the lathe. Frequently the thread is originated by making a spiral line with the die stock, the work is then transferred to the lathe where the screw is cut out with the comb tool, this cutting faster and better than dies, and being comparatively easy to keep in the spiral originated by the dies. If this is not quite true it is not likely to be improved in the chasing by any but a skilled screw-cutter. After the bulk has been removed by the comb tool the dies are used to finish with. To acquire the habit of traversing the tool at a uniform rate a beginner should practise on a cylinder which has a thread already cut on it, such as one partially cut by dies.

The way in which the screw thread is originated by hand with the chaser will be easily understood. It is simply necessary to move the chaser along the top of the T-rest exactly the same distance that the teeth are apart whilst the work is turned round once. If the tool and work have been moved at a regular speed the thread will be true; if, however, either motion has been jerky the thread will not be regular but bent or wavy. It will be seen that

the rate of the screw and the diameter each govern the result, and though the difficulty of striking the true thread may appear very great, yet after careful practice and observation of the result it will be a job that can be done with ease and certainty.

The thread, whether outside or in, is always first struck on the corner of the work, and this is rounded off for the purpose before applying the screw tool. The T-rest, which must have a smooth top, is then placed near to this corner, and having set the lathe going with a regular swinging motion, the comb is brought on to the rest. By a circular motion of the handle, the blade of the tool having a centre of motion on the top of the T, one tooth near the centre is made to cut a spiral line, the depth of which is greatest at its middle and diminishes to nothing at the ends. When once the true helix is struck it is comparatively easy to follow it up, making it deeper and extending it further at each application of the tool.

The thread is thus struck at the end first, and gradually deepened and lengthened till it has reached the distance required ; so that during the process of chasing it the thread is always cut deeper at the end, and it is made parallel by giving the final cuts nearer to the back end. The first spiral traced forms a guide, and on repeating the cut the point of a tooth must come in the previously-made groove, or the thread will be damaged and probably spoiled. Those who have cut threads with badly fitting dies have probably had occasion to

notice the effect of another thread being originated between the true one; this is what happens if the comb tool is not always put into the first made groove.

The use of the comb-screw tool for inside work is best explained by its application to cutting the thread in lathe chucks, after starting with the tap as described in Chapter VII.

When the thread has been started in the hole and the tap taken out, clean the dust out of the hole and put the hand-rest, which must be quite smooth, at least at that part where the screw tool will take its bearing, close against the hole, at such a height as may be convenient for allowing the chaser to cut. This will be with its edge slightly above the centre, as the rake of the teeth is, in bought screw tools, the wrong way, and in consequence of the thickness of the tool it would, if placed at the correct height—*i.e.* on the line of centres—have the lower points of the teeth in contact with the interior of the hole. If these points were to find their bearing in the spiral groove, the upper cutting edge would not cut at the same spiral line, but a trifle behind it. Thus will be understood the importance of getting the tool to the correct height to let the lower edge escape contact. When all the parts are properly adjusted commence cutting the screw. First get a regular swinging motion to the lathe-treadle; the habit must be acquired of keeping the same regular motion with the foot, independent of the occupation

of the hand. Hold the comb-screw tool with the right hand firmly gripping the handle, and the left steadying the tool by having the fingers round the socket of the T-rest, the thumb grasping the chaser near the rest and pressing it firmly into the thread. At first it is advisable to let the tool run in along the thread a few times without cutting, thereby to get the rate of motion impressed on the senses, so that the rate of progression of the tool can be maintained by muscular action as well as being guided by the spiral made by the tap. Having got the rate of motion, take very light cuts at first, but always be sure to have the teeth in the original grooves, otherwise, there is every probability of getting a multifold thread. When the comb is placed near the mouth of the hole with about three teeth projecting inside, the left thumb is used to draw it towards the side of the hole. As soon as it is felt to be in the screw groove a heavy pressure is maintained to keep the chaser up to a full cut, till it has run in right to the bottom of the hole. The tool should be held in such a position as to insure parallelism of the teeth, so that the thread will be cut of equal depth throughout its length. The inexperienced hand runs great risk of coming to grief over screw-cutting, but practice will make perfect, and it is only after repeated trials that an amateur can expect to be able to run in a true thread with the chaser. Care must be exercised not to let the tool go in far enough for its point or end to come in

contact with the bottom of the hole whilst the teeth are cutting the thread, or damage more or less serious according to the rigidity with which the tool is held must inevitably follow. The eye and hand will soon become educated to act in unison, so that when the screw tool has gone in to a certain depth, as indicated to the eye, the muscular power of the thumb is relaxed; the teeth of the chaser are gently drawn out of the thread, and when quite clear the tool is drawn outwards, say half an inch or so, and the operation repeated. This is continued till the thread is nearly to size, and it is finally finished with the full tap. There are several points to be considered in cutting the thread. As to its size, if the chaser is too high up it will cut the thread shallower than it should be. If the tool is not run in parallel, the mouth of the hole will not gauge correctly, and consequently it will be impossible to ascertain the exact size of the thread. These points must be studied and acted upon to the best of one's judgment, any definite rules being impossible.

When the thread has been cut out with the chaser to, as near as can be judged, the proper size, the full-sized tap is inserted and screwed home exactly the same way as was the entry tap, using the back centre to keep it square, and working it right in till it "bottoms" in the hole.

CHAPTER V.

BORING AND DRILLING.

Drills, their correct form and uses—How to grind them—Half-round bits—Pin-drills—Bars with movable cutters—Rose cutters and rose bits—Lubrication necessary in boring.

BORING and drilling form a large proportion of the work done on a lathe, and embrace the various methods employed to pierce holes and smooth internal cylinders. Drills, bits, cutters, and many other tools are used for making the holes; slide rest tools, boring bars, broaches, &c., are used to smooth holes already existing.

Drills are the most generally used of all tools for boring holes of all sizes. When these are too large to be made in one drilling, two or more drills each of a size to bore out a proportionate quantity of material are used. It will be found hard work to bore holes larger than half an inch in metal on a foot lathe at one traverse, and it is, therefore, advisable to use three drills for a hole $\frac{7}{8}$ inch in diameter, that being three times the area of the largest size that can be bored without considerable fatigue. The first boring $\frac{1}{2}$ inch, the next $\frac{1}{4}$, and the third full size $\frac{7}{8}$; the work of removing the material will then be

roughly fairly apportioned to each tool. A drawback to the use of drills is that they are liable to run out of the straight line in which it is intended to bore, and the drill cutting into the solid material is most liable to do so. Those which follow on generally keep fairly true to the original hole, but they have no tendency to correct any error, and are sometimes found to increase it. Drills should always be started in a fairly countersunk hole, and especial care taken to see that they go correctly in the spot desired till the entire point angle of the drill is beneath the surface; the sides will then tend to guide it.

Fitted to a chuck such as those described on page 92, the drill is the most usual form of borer, as its point will at once find its bearing in a centre punch mark and follow on fairly concentric, sufficiently so for the majority of purposes. Thus for all the general purposes of boring where absolute truth and straightness are not imperative, drills are the best tools to use. It is only necessary to indent a conical hole with the centre punch, sufficiently large to allow the flat end formed by the meeting of the cutting edges across the thickness of the drill to enter well, and the hole will follow fairly true. If a long cylinder has to be bored then a drill would be unsuitable, as it would be sure to deviate from a straight line, and, though entered perfectly central at one end, on reaching the other it would come out more or less out of truth with the centre. This fault is sometimes sought

to be remedied by drilling alternately from both ends and making the holes join in the middle, but here they do so only approximately. Though apparently true from what may be seen at the ends, yet when looked at through the bore will be found to be crooked.

The ordinary form of drill is shown in Fig. 2. The shank part is turned parallel to fit a chuck, and a flat filed to take the point of a clamp-screw. A shoulder, to prevent the drill being forced into the chuck, should be provided as illustrated. The entire drill should be nearly parallel; if small at the point-end it will not bore deep through binding,



Fig. 2.—The Drill for Boring Metal.

and if unnecessarily small at any part behind the point the drill is weakened and liable to break. The blade should be flattened sufficiently far to allow borings to escape. The illustration is intended to convey to the eye an idea of the best general form of a drill for ordinary purposes.

Drills must be ground with their points at an angle of 90° , so that they fit an ordinary right angle square. The extreme point must be in the exact centre, and the flat part of the drill should be nearly parallel on its sides for a short distance from the point, as this will materially assist in guiding; the cutting angle must be small, only sufficient for proper clearance. On taking into

consideration what has been said on the cutting edges of tools in another chapter, it will be understood that the proper form of cutting edge for a drill is that of the American twist drills, which act with far superior results to those of the usual form. To grind the cutting edge more acutely by increasing the angle of the bevel, does not produce the same result as when the point is turned up to form a cutting lip, as is the case in the twist drills.

To get the cutting edges to correspond in every respect is essential, so that the drill will act with the best possible results. The point excentric or one edge more prominent than the other will tend to make the drill bore larger than its intended size, and innumerable defects inherent to the tool will develop themselves. The blade must be as thin as is consistent with due strength, so that the material removed in borings may pass along on either side of the drill and not clog the hole. By noticing the quantity and quality of the borings an idea of the relative shape and action of the cutting edges may be formed. Sometimes it is desirable to bore a hole larger inside than at the mouth; this may be done by grinding the drill on one edge only, so as to throw the point out of centre; used in this way the tool will bore larger than its apparent size.

Half-round or D-bits are the sort most generally used for boring holes parallel and straight. These are made by filing a cylinder down to half its diameter and then grinding the end off obliquely.

The description will be found on page 73. These bits are made of all sizes, some used for ornamental work being most minute. They will bore a hole into solid metal, but are more often used to follow a drill and correct any defects left by it. It is only necessary to make a countersink to fit the D-bit correctly ; it will then bore quite straight, but it must itself be straight and be revolved straight. The half-round part must not exceed the semi-diameter, or the bit cannot bore a hole in solid material. An advantage which this form of boring tool has is that it leaves the hole with a flat bottom, not a conical one as drills do. When of large size, these bits usually have a portion wanting to complete the semicircle on the opposite side of the flat. This results from their being made from flat bars of steel not sufficiently thick to form the entire half-round ; it in no way detracts from their utility.

Pin-drills are used to bore a larger size truly concentric with a previously made hole ; also for making square countersinks for screw-heads, &c. Somewhat similar to a drill in their action, these tools have a round pin at the end, and the cutting edge is behind this. Generally they have but two cutting lips, but, when made of round steel, pin-drills have usually four cutting edges, as illustrated in Fig. 3. The pin fitting the hole previously made effectually prevents the drill from going excentrically. In order to make one drill serviceable for different-sized holes, collars are

sometimes fitted to the pin, and by this means it is adapted to larger holes. Pin-drills, often made in the cutter bar next described, are very useful for making a level bearing for a nut or a bolt head against a casting. By using this drill a circle of any size required may be made quite flat and smooth, concentric with a hole bored in a rough casting. By shaping the cutting edges to the necessary form these tools may be used not only to face up but also to true the edges of bosses, &c., that cannot be turned in the lathe, and even to put a moulding round them.

Cutters are sometimes used fitted to a bar, which is revolved between bearings or on the lathe centres; then the cutter is at some distance from the end, often near the centre. When near one end of the bar it forms a kind of pin-drill. These bars are always for boring large-sized holes, and are made from motives of economy, one shank or stock serving for a large number of cutters often having a wide range of sizes. The cutters to such a bar can be made in so little time and at such a very small cost that the advantage is obvious for all sizes that are not usually required. The bar itself may be of iron, though preferably of steel, and after being centred and trued up, it has a transverse mortice cut through it near the end. The end is then turned to a certain size to follow drills or half-round bits of that size. The cutters for the bar consist of small pieces of steel wedged into the mortice by a cotter. The cutters

have a groove across them, leaving nibs to fit over the diameter of the bar and ensure their being replaced true. When the blank has been fitted to the bar, it is turned true in its place to the required size, the cutting edges are shaped by filing, and the cutter is hardened and tempered for use. Sometimes the cutters are clamped in the mortice by a set screw.

Rose-bits have several teeth on the end to cut with; some are made quite flat, and are used for cutting recesses of small depth that are required to



Fig. 3.—Pin Drill, with Four Cutting Lips.

have a flat bottom with no hole in the centre. This form of rose-bit does the work of a pin-drill without requiring any thoroughfare hole to guide it. The bit is guided by clamping a piece of sheet metal having a hole in it exactly fitting the rose-bit, and this placed in the hole bores straight away; therefore it is only necessary to place the hole of the plate precisely over the spot that has to be drilled. These rose-bits will not cut into the solid metal, but for some purposes they are indispensable. Fig. 3 without the pin would illustrate a rose-bit.

Rose-cutters made in the same way but with a central hole are used to make pivots. A piece of metal that has been pointed is brought against a cutter of this kind, which then cuts away all the metal within its diameter excepting a cylindrical piece which passes up the central hole and corresponds with it in size. This pivot serves to keep the cutter in position. A hollow rose-bit of this kind fixed into the poppit barrel is a capital tool for making screws with, as at one operation it will cut down the material to a uniform size to take the thread and leave it perfectly cylindrical with the head and shoulder cut in square. For making a projecting pivot-like piece of a casting, that cannot be mounted in the lathe, true and smooth for a bearing, these cutters are also very handy.

Rose-bits with cutting teeth on the end corner only are used for boring holes that are required to be particularly smooth and true. When once entered a bit of this kind cannot go wrong, as the cylindrical part accurately fits the hole bored by the teeth; these are never used except in holes that are very nearly sufficiently large. The hollow rose-bit may be used as a pin-drill by putting a tight-fitting cylindrical plug in the hole with sufficient projecting to answer for a pin. Rose-cutters of all kinds should have the teeth sufficiently large and wide apart to allow of the borings to escape, or they become clogged up if the teeth are fine. Another advantage in large teeth is that they may often be sharpened on the oilstone; this cannot be done

with small ones. For half an inch in diameter from four to six teeth will be enough, and when at work they should each do their share of cutting.

Lubricants are required in boring wrought iron and brass, soapy water answering very well, but it is necessary to see that the liquid really reaches the cutting edges. This is sometimes difficult to ensure when boring deep holes horizontally, as they are on the lathe. The borings generally block the way, and even when the hole is clear it is not easy to get any fluid to the bottom of it if deep. A small common syringe is handy for the purpose, but it is only by constantly removing the tool, and with it the bulk of the borings, that the extreme end can be reached even with a syringe. Cast iron can be bored very well quite dry; but with pin-drills and others, that make a bearing as it were of the material into which they are drilling, a lubrication is necessary for all materials to relieve the friction at the bearing part.

CHAPTER VI.

MOUNTING WORK FOR TURNING.

Work between centres — Methods of centring — Necessity of properly preparing the centres—Chucking objects of various forms—False centres—The collar-plate—Chucking on the face-chuck.

WORK is mounted for treatment on the lathe in various ways, consequent on the almost unlimited forms which have to be chucked. There are two broad distinctions, however, by which we may conveniently divide the methods in general use for ease in describing them. First, objects which are supported by the back-centre, cone-plate, or some equivalent contrivance; and second, those which are mounted on the mandrel independent of such support. Amongst the first are generally all objects considerably greater in length than diameter, such as balusters, spindles, and rods of all kinds; the second, embracing short objects, sometimes gripped by their edges, and at others clamped by their surfaces, or held by cement in a similar fashion. In the chapter devoted to chucks much information applicable to this subject will be found.

The method of mounting work by far most generally practised is that of running it between centres.

The extreme facility of so chucking any object capable of such treatment is the chief cause of its extensive use, whilst its effectiveness leaves little to be desired. The indented, shallow, conical recesses to be seen at the ends of nearly all spindles and shafting are evidence of the work having been turned between centres by the aid of such a chuck as the one illustrated in Fig. 9. Work that has been once properly centred may be removed from the lathe, and at any time remounted on any other with the certainty of its running true, that is, providing the centre-points of such lathes are in proper order at the time the work is put between them. Other methods of chucking do not allow of this being done without considerable trouble, and hence all work that has to be often removed and replaced on the lathe should, if possible, be chucked between centres.

The first consideration in preparing work for running between the centres is to get the exact centre-point at each end, so that the entire object will run true on the lathe, and not, by being considerably out of centre, involve a great deal of unnecessary labour in reducing it to a concentric form. It is curious to find that an inexperienced hand seldom attempts to get an accurate centre to his work, and many consider the trouble involved in so doing far outweighs the advantages. It is, however, so easy to centre work absolutely truly that the extra labour is comparatively inappreciable; in fact, only a slovenly hand would tolerate badly-

centred work, involving as it does so much extra labour to no purpose.

Rod metal is, perhaps, the most usual object for centring, and in selecting a piece for a particular object it should be chosen just sufficiently large, both in diameter and length, for the purpose. All superfluous metal will be wasted, and not only that, but the labour which converts the good material into useless waste is itself all lost. The rod should be straight and the ends cut off squarely; these are each in turn filed flat, and at right angles to the axis of the rod. If the end-faces are at a slight angle it is more difficult to judge of the centre of the rod. The try-square will show the inclination of the end-faces with the side of the rod, though a practised eye will, unaided, detect the most minute error appreciable in working.

The actual centring is done with a fine-pointed centre-punch usually. For work of small diameter the punch is placed as near the centre as can be judged by the eye, the work being meanwhile held vertically in the vice, and a light blow of a hammer indents the metal. The rod-end is then carefully examined, and if the dot is found to be out of centre it is driven towards that side of the rod where most metal appears; this is done by holding the punch in a slanting direction when striking it. When the dot is judged to be fairly central the rod is reversed in the vice and the other end treated similarly, the punched centres being only slight. The rod is then placed between

the lathe-centres, and by turning it round with the thumb and finger, the amount of its eccentricity, if any, can be noted and the high parts marked with chalk. The rod is then returned to the jaws of the vice and the centre-punch applied so as to drive the indentations towards the centre. The work is again tested on the lathe-centres and operations repeated till the rod is found to run true. When this is accomplished the punch-marks are considerably enlarged by heavy blows, holding and driving the punch in a straight line with the rod, a stronger punch being employed.

Drilling in the centres is the next operation, and an important one it is for work that has to run on its centres much, though for work that will never be put on the lathe a second time it is sometimes dispensed with. Some workmen, careless of the accuracy of the work they turn out, are content to use centre-punched centres only. In every case when the work is liable to be run between centres on a future occasion, the punch-marks should be drilled in with a small drill sufficiently deep to ensure the centre point from bottoming; the hole should also be slightly countersunk to form a durable bearing for the centre when running. The depth of the hole, size of the countersink, &c., will be dependent on the size of the work, but in all cases the countersink must bore to the angle corresponding with the centre-point, this being, as

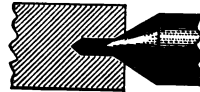


Fig. 4.—A properly drilled Countersunk Centre.

stated in another chapter, 60° . The hole bored in the work may be very small, but must be deep enough to clear the centre and allow for a little wear. Fig. 4 shows how a properly drilled and countersunk centre-rod should fit the cone-point; the rod only is shown in section.

Rods of large size, and those objects that have to be centred at parts where it is difficult to judge of the precise centre, are usually marked with callipers or a scribing-tool to show the middle. A gauge formed of two strips placed at an angle, and having a straight edge bisecting the angle, can be used for determining the centre by putting the rod into the angular opening and scribing on its end two diametrical lines at somewhere about right angles to each other, the intersection of these lines showing the precise centre. A centre-punch sliding in a barrel at right angles with and forming a continuation of the apex of a hollow cone is also employed, though not very generally. The cone is placed vertically over the end of the rod to be centred, and on bringing down the centre-punch it will mark the centre of the object within the cone. In practice this form of centre-finder is confined to the workshops of amateurs.

A totally different method of centring cylindrical rods may be adopted, and when many of like size are to be treated it has advantages over the centre-punching previously described. By this method a centre fitted into the poppit barrel, having its end ground off to a triangular point, is employed

to bore a countersunk hole, its exact central position being ensured by causing the work, which is itself chucked by a temporary punch-mark on the point-chuck, to revolve against some fixed support near its outer end. See illustration, Fig. 5, showing a rod being centred. An L-shaped tool resting on the T-rest, and supporting the work in its angle, will serve every purpose, and by forming a bearing for the rod to work on when the boring-tool is brought up by the poppit head the central position of the hole is ensured. In practice it is usual to



Fig. 5.—Centring Metal Rods on the Lathe.

centre both ends of the rod roughly with a punch, and then by boring only lightly to gradually correct any error by the aid of the L-tool mentioned above, or by a bar fixed in the slide-rest, with a V-slot, in the sides of which the work may take a bearing, and brought up till the rod bears in the slot during the whole of its revolution. The triangular point of the centre, Fig. 6, cutting sideways as well as in the direction of its point, soon cuts towards the highest point of the excentric rod, which is continually pressed towards the centre by the fixed bearing, against which it touches at every

revolution. A stiff triangular point is necessary—flexibility would destroy its purpose—and the countersunk hole must be drilled in, as in Fig. 4, with as small drill as has been already described. Work centred by the method last described is, of course, reversed in the chucking when one end is finished, so that the other may be operated upon.

It will be understood that innumerable objects of various forms may be chucked by simply making sound centres in them; for these, though they may appear but fragile bearings, are really strong enough for every practical requirement if they are only

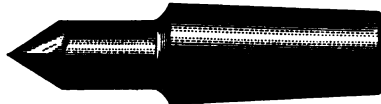


Fig. 6.—Poppit Centre, with Triangular Cutting-point.

correctly made, as Fig. 4, in the first instance. Square bars that have to be turned with cylindrical parts, as, for example, the ordinary grindstone axis of square section, with a bearing near each end, are easily operated on when running between centres.

In some cases, where work has not a suitable place for centring in a line with the axis on which it should be turned, a piece is put specially to afford a centre bearing. Sometimes the casting or forging is so prepared, and in others a piece is fixed by some means. As an example we may take a crank-shaft, which to be chucked, with the main-shaft excentric and the crank-pin running true,

has a piece of metal fastened at each end, projecting sufficiently to allow of a good centre to be made in a line with the crank-pin itself. It may be taken as an axiom that, whenever possible, between centres is the best way of chucking all metal objects in the lathe.

The collar-plate is an appliance for supporting work which cannot be conveniently held in a chuck without support at the outer end, when this outer end has to be operated upon, generally for boring up. The collar-plate, previously mentioned, is a circular plate, usually of cast iron, with a series of conical holes, the sizes of which vary progressively, bored near its circumference equidistant from the centre. This plate is mounted by a central hole on a dwarf casting fitted to the bed, and fixed by the bolt, on which it may be turned when this is slackened for the purpose. The shank of the bolt passing through the casting is square, and sometimes passes through a vertical slot, which allows adjustment for height, but it is better fitted accurately to a square hole in such a position that each coned hole is on a level with the line of centres when at its highest point. For use the collar-plate has simply to be adjusted to the correct distance to form a bearing for the object it has to support, a hole of suitable size having been first determined on and placed uppermost; the extreme edge of the work bears in the hole, and should be slightly bevelled to prevent cutting, a little oil being also necessary for lubrication. In this position the

object is ready for being bored up centrally and for similar treatment.

Work mounted for turning on a chuck, and fixed to it, independent of support from the back centre, if of a concentric form is usually held by its edge in a recess turned in the chuck itself. When the fitting is made fairly accurate, and the work is itself tolerably true, this method will secure it firm enough for most purposes. When the work is of angular outline it is best to have three points of contact, which ensure equality of grip if the points are equidistant. In chucking square objects by their angles it is necessary to see that the two diameters across the angles are equal, or the object will be fixed only at two points. When there are but three points all must be in contact; for this reason, three screws in such a chuck as the one numbered Fig. 15 are preferable to four.

The face-plate is, perhaps, the most generally useful chuck for all objects which are capable of being fixed by one side, whether the side itself be sufficiently flat for the purpose, or whether the work be made level by packing. The face-plate chuck is described on page 95, and work to be fixed to it is laid on it and clamped firm, using preferably three points of pressure if that part of the work laid on the chuck has not already been made perfectly flat by turning, planing, filing, &c. Sometimes it is easier to fix work on the face-chuck when this is lying horizontally; at others, *the central* position of an object is maintained by

means of the back-centre point supporting it whilst being fixed. Only the peculiarities of the job in hand can determine the most advantageous manner of placing it on the chuck ; and, in short, every particular piece of work of an irregular form generally possesses certain special features which at once offer advantages for chucking it, or the situation of the part to be operated upon makes the adoption of certain positions on the lathe essential. Even two equally competent workmen, who have been taught—or, perhaps, it would be more correct to say, have picked up their knowledge—in different shops, will chuck the same object in totally different ways.

CHAPTER VII.

FITTING CHUCKS TO THE LATHE-NOSE.

Minute details of the process—Various threads used for lathe-noses
—Making taps, &c., for fitting chucks—How the thread should
be formed—A truly cut thread necessary on the nose.

CHUCKS are those appliances which, screwed on the nose of the lathe, are used to cause the work to revolve. The variety of work turned on the lathe involves a corresponding variety of chucks, and though the turner who produces only one species of work, as, for instance, stair balusters, only uses one single chuck, yet the amateur turner, who provides a lathe and attachments capable of grappling with work of all descriptions, will find his stock of chucks amount to several score. Those complicated apparatus which involve a lot of mechanism in themselves, such as are used for turning excentrics, ovals, and geometric figures, will not occupy our attention in the present treatise. They are mostly costly tools, and are seldom found in the workshop of the general turner, though an oval chuck is the principal tool of the oval turner, and the engine-turning lathe with geometric apparatus is the every-day tool of watch-case engine-turners.

Chucks are usually added to a lathe by the turner as occasion occurs, because in making them the greater part of the work as a general rule has to be done on the identical lathe on which the chuck will be used; consequently full details are here given which will enable those readers who are able to execute the work to make for themselves. One of the first considerations in a chuck is that it should be fitted correctly to the nose of the lathe, and general directions for effecting this precede the more minute instructions incidental to each chuck. To fit chucks accurately, as they should be fitted, it is necessary to have a screw-tap which cuts the thread identical with that on the lathe-nose. It is, however, quite impossible to cut a full thread in a "no thoroughfare" hole with one tap only, and in consequence of the depth of the thread usually used for a lathe nose, it is inexpedient to cut out a perfect thread by the aid of taps alone. Therefore, instead of taps a comb screw-tool is used to cut out the bulk of the material to form the thread. To use this screw-tool requires a good deal of practice, but by starting a true thread by means of a tap, and carefully following up the spiral scratch made by it with the chaser or comb, the thread will be cut out with tolerable truth. Any slight error will be easily rectified by the full tap when that is put into the hole. Those who are already provided with taps and chasers for cutting the threads in their chucks will not need these details; but as comparatively few

lathe-makers provide these essentials as part of the lathe, it will be advisable to go into minute particulars for making the set of tools requisite for boring and screwing chucks.

With regard to the length of the nose, it is easy to understand that the longer it is the further from the mandrel bearing will the work be, and consequently the more liable to "chatter"; whilst, on the other hand, so long as the nose thread contains enough turns to make it perfectly safe from stripping, there is no other limit to its shortness, providing always that there is enough whereon to screw a chuck. Holtzapffel's and Whitworth's lathes have noses of a length equal to their diameter; and there are scarcely better authorities to be cited on the subject. Having determined so far the proportion of the nose that the chucks are to fit, we will proceed with the description of the tools required for boring and tapping chucks to the $\frac{3}{4}$ -inch Whitworth thread.

First a D-bit is wanted to bore out the hole to the exact size required for cutting a full thread, after which must follow the entry-tap. The D-bit will of course be made to bore $\frac{1}{2}$ inch diameter. To make this take a piece of cast-steel bar $\frac{3}{8}$ ths full by $\frac{5}{16}$ inch, and say 4 inches long. Having softened or annealed this piece proceed to centre one end carefully. Bend the other end over as short and sharp as you can so as to get a good sound centre-punch mark on it, which will allow the bar to run out of true, so that at a short distance from the end

the material will lie all on one side of the line of centres. Fig. 7 shows the piece of bar chucked between centres as explained above, A and B being the centre points, and the dotted lines being the line of centres. At C, the steel lies all below this line of centres, and, of course, runs very much out of truth at that part, so much so that when a cut is taken along it with the slide-rest, and the diameter reduced to $\frac{1}{2}$ nds, the section will form a semicircle. This will form the cutting part of the D-bit, the back part of the shank being turned

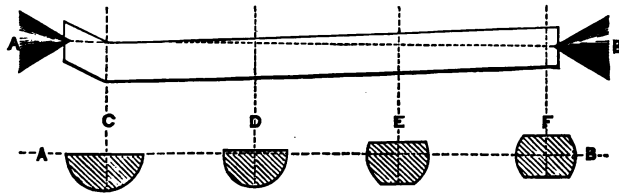


Fig. 7.—Making a D-bit.

down smaller to clear properly, as shown by a series of sections drawn under the bar. At C is shown the full-sized part which has to do the boring. It is turned nearly parallel to the same size a distance equal to the depth of the hole to be bored, that will be, allowing $\frac{1}{8}$ inch for clearance, at the end of the nose, $\frac{7}{8}$ inch. By leaving this part the exact length, it forms a gauge by which you can judge of the depth of the hole, and cease boring when the bit has gone in so far. The remainder of the bit can be turned parallel, say $\frac{3}{32}$ nds or so less in diameter all the length, and that part, near the

end F, will be fairly flat on both sides, forming a convenient grip for a hand-vice, or hook. When the entire bit has been finished, that part shown to the left of C in the drawing must be cut off, but it is as well to leave just a little piece to form a lip to assist the cutting. Before this end piece with the centre in it is finally cut off, the bit must be smoothed with a superfine file, so that it will bore without tearing away the material. It should also be made to taper very slightly—only a barely appreciable amount is enough, so as to relieve the back part of any cutting, which would be so much unnecessary work, and tend to make the hole tapering. Having finished shaping the D-bit, it must be hardened and tempered.

Two taps will be wanted; an entry and finishing size. Square steel should be used for making these taps, as it is not so liable to warp in the hardening as round steel is. Best cast must be selected, and it may be forged up to shape at a red heat, but on no account must it be overheated or “burnt”; this will spoil the steel, and it had best be thrown on one side at once, for a satisfactory tool cannot be made from burnt steel.

There is not much difficulty in turning down the square stuff in the lathe without any previous preparation, and this will be the best plan when a forge is not easily come-at-able. The length of each tap may be, say, from 3 to 4 inches. For our $\frac{3}{4}$ Whitworth we shall require one of the rough pieces to be fully $\frac{3}{4}$ inch, and the other $\frac{1}{2}$ ths.

Select two pieces which will finish to these sizes ; centre each quite truly, and test the truth of the centrings before drilling and counter-sinking, then true up the ends. Divide each into three equal lengths, making a nick at each division with a file. That end which is to be the square part of the tap, on which the wrench or spanner will ultimately be placed when the tap is in use, may be left the full size of the square steel, and occupy one-third of the length. The remaining two-thirds will be reduced to $\frac{3}{4}$ inch and $\frac{3}{16}$ nds respectively, these being the external diameters of the "full plug" and "entry taps." The method adopted for cutting the thread on the taps is a matter of detail, which will be governed by the appliances at hand. But whenever possible the thread should be cut out very nearly to the full depth by means of a single point tool in the screw-cutting lathe. This ensures a true thread, which is most desirable, though unfortunately not always to be found even on the mandrel nose. Some lathe-makers adhere to a standard size and rate of thread for their lathe noses, which it is in some cases impossible to cut exactly with the ordinary change-wheels. This seems an unaccountable circumstance at first sight, but it is explained by the fact that threads were in extensive use long before screw-cutting lathes were thought of. In the old threads their rate was simply dependent on the caprice of the workman, who had no idea of, or cause to keep in view, a system of aliquot parts when originating a thread.

Thus we find Holtzapffel's threads, which had been cut before the advent of screw-cutting lathes and by duplication, have become now almost universal, are all odd in their rates, and the pitch is usually given in hundredths of a turn to the inch. For an example of the irregularity of threads we will cite those used by Buck, Evans, and Holtzapffel for their 5-inch lathes.

	Diameter.	Rate.
Holtzapffel . . .	25-32nds.	9'45
Buck	3-4ths.	10'
Evans	13-16ths.	9'5

Whitworth's standard is the one to be recommended in preference to any, as it is comparatively easy to get any screwing tackle to match his rates; taps, screw tools, &c., being sold in the tool shops exactly fitting. The shape of Holtzapffel's threads differs from Whitworth's, inasmuch as they are cut with a tool ground to an acute angle, without any rounding off at all.

The section and elevation of the tap shown in Fig. 8 is the finishing size, the thread being cut at the left-hand end to the exact size; so that when a chuck is tapped with it, it will screw on to the mandrel nose easily, yet without shake. Chucks ought to fit too tightly to allow of their being screwed on with any dirt or metal borings inside the thread. Most chucks are made so large in the screw that this is of no consequence, and the result is that they are screwed on with chips of metal adhering to the thread, and the chuck is thus made to run

out of truth. If kept clean, as they must be when properly fitted, they must always screw home true to the shoulder, and thus save an immense amount of trouble. If a tiny fragment of metal does get firmly fixed inside the chuck-thread, it can easily be removed by the aid of the tap, which is the proper thing to use for the purpose, if a stiff brush or peg of wood fails; to mutilate the thread with a graver or other cutting tool is very bad practice.

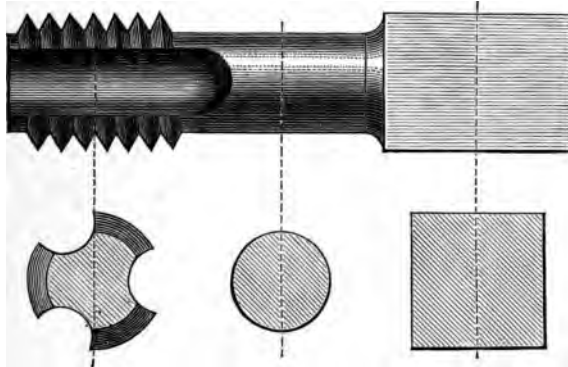


Fig. 8.—Tap for Screwing Chucks.

The length of the screwed part of the tap is just $\frac{3}{8}$ inch; so that it screws in to the last turn when right against the bottom of the hole, bored, as before directed, $\frac{7}{8}$ inch deep. The round part immediately behind the thread is made to the exact size of the bottom of the screw, and thus forms a gauge for the tapping size of chucks. The square part is the full size of the steel, from which the tap is made. This saves the trouble of reducing the

size by filing, and also gives a larger square to catch hold of. This is convenient in clearing out a chuck, as the large square affords ample grip for the hand, and there is no occasion to use a wrench for that purpose. The sections just beneath the large tap show the shape of it at the thread—the round part—and the square.

The entry tap is precisely similar in shape, only that it is smaller in diameter. The thread is cut to the full depth, and the tap is very nearly parallel. It should have the first two threads filed down on the tops slightly, so as to distribute the amount of work to be done over, say six cutting points. It is a great mistake to leave but one full thread at the commencement to do all the work, as in that case the tap is liable to be made to cut unequally, making a deeper thread at one side of the hole than at the other. If the tap is grooved at three places, then the two first turns of the thread will give six cutting points, and these must be filed down in a series of steps, so that each one does a fair share of the work. This tap is only meant to cut a shallow spiral to guide the comb-screw tool. By this method a true thread—*i.e.*, one which is not drunken—will be originated, and it only requires care on the part of the operator to keep the teeth of the comb in the groove traced by the tap, and a true thread will be maintained till the end, absolute accuracy of parallelism and diameter being insured by the use of the finishing tap, which will also assist in correcting any slight “wobbling” which

may be imported into the screw during the chasing by hand.

The illustration Fig. 8 shows the tap to be grooved straight lengthways, and of course these must be made before the taps are hardened. There are several plans for making cutting edges. Semi-circular grooves cut by a circular cutter are perhaps the best, when the necessary tools are within reach. The groove should take up one-sixth of the circumference; there being three grooves, this allows an equal amount of groove and thread. If a milling apparatus is not available, a somewhat similar groove can be cut with a round file, spacing out the divisions by the eye, and filing each groove as nearly equal in size as possible. A better plan is to file them in a spiral direction, making each groove take about half a turn round the tap. This produces a better cutting tool, and the file can be brought to bear on the tap more conveniently in a slanting direction. Some little practice will be required to enable one to make the grooves all of an equal twist and shape, so that the tap will look workmanlike; but so long as the grooves are cut in to a proper depth, there is no necessity to have them all alike, though it improves the appearance. The cutting and back edges must not be left too acute, or they will be liable to be broken off when the tap is in use. The groove should be something like a shallow semicircle in shape.

Having described the method of making the taps and D-bit, we proceed with instructions on their

use. Suppose a metal chuck—cast iron, gun metal, or whatever may be the material—is to be fitted, the first operation will be to chuck the casting firmly in the best manner available, according to its shape and the tools or appliances at hand. It should be fixed so as to run as truly as possible and be quite firm, as the process of tapping will strain it very much, and it is very vexatious to get the work thrown out of truth when it is nearly finished. To set it true again is not a difficult job to the experienced hand, but a beginner generally looks upon such a mishap as almost a death-blow to his symmetrical work; therefore, secure the casting so that it will be immovable, and yet not strained to be distorted. Having the casting firmly chucked, and running as true as possible, proceed to face up the shoulder surface all over. The best plan to do this will be first to turn out a sort of counter-sunk hollow in the centre, by means of the graver and hand-rest; then to use the slide rest to turn the face flat.

Probably two or three cuts will suffice to produce a level surface, the last cut being made as fine as possible to leave a smooth shoulder. Now remove the slide rest, and with the graver carefully run a centre to take the point of a drill, say about $\frac{1}{4}$ inch or $\frac{3}{8}$ inch diameter; start the drill truly, and bore down to the depth required for the hole, which will be $\frac{7}{8}$ ths of an inch. This small hole having been drilled, it must next be enlarged to a size approaching that of the D-bit. The methods of enlarging

are numerous, and the one selected must be left to the workman, who will best know which suits the circumstances of his particular requirements. A small inside or boring tool may be fixed in the slide-rest, and the hole enlarged by this means. This plan is particularly suitable. If the boring has run much out of truth when drilling the first hole, it will be necessary to exercise caution in using a fine tool, such as the limited dimensions of the hole will demand, more especially in getting to the end of the cut at the bottom of the hole, as should the tool be allowed to go but a trifle too deep it will dig in and probably break off. After some little experience with these tender tools they will be found to work well, and a breakage will be of very rare occurrence. Another way of enlarging the hole will be by means of another and larger drill put in to follow the first; this must be started true by turning a chamfer round the edge of the hole to fit the end of the drill. If the first hole has gone in pretty fairly true, the second will follow about the same; but of course if the first hole is crooked, the second drill will not make it straight. This plan must not be adopted if the original hole has run much out of truth in drilling, but instead of a drill a D-bit may be used, and this, if started true, will bore true, without regard to the previous boring; so probably this will be the tool most generally suited to the work.

The D-bit made specially to bore the exact size for tapping is not the tool now meant, but a simi-

lar one which bores somewhat smaller in diameter. It would be quite possible—in fact easy—to put this full-sized D-bit in immediately following the small drill ; but to save the tool and ensure greater accuracy, it will be best to only leave a light cut to be taken by this finishing-size D-bit.

The full depth will be accurately determined by this D-bit, which will also cut the bottom out quite square. This is an important consideration, as the points of the drills would leave it very much coned. For many other purposes it is advantageous to have a hole bored with a flat bottom. Numerous instances occur throughout this treatise where explanations that are given with the details applied, more especially for some particular work, may be construed to suit various other processes of an analagous nature. It is easy to fix a collet on to the shaft of the D-bit to form a gauge and prevent the bit boring to too great a depth. This expedient is not necessary when the tool is used by a practised hand, who sees at a glance when the desired depth has been attained. Any slight mark upon the shank of the bit serves as an indication by which to work.

When the hole is bored out to a trifle over $\frac{1}{2}$ inch the finishing D-bit is brought into requisition, and the hole bored to exact diameter and depth, as before described. The next operation, though it is often dispensed with altogether, should be to undercut or turn a ring round the bottom end of *the hole* to the diameter of the outside of the thread.

This groove must be made with an L-shaped slide-rest tool; the breadth is immaterial, about an eighth to three-sixteenths of an inch being the most convenient. The object of this groove is to allow the comb-screw tool, which is used to cut out the thread with, to cut to its proper depth at the inner end, and in fact makes the short hole almost like a thoroughfare for the tool in working, thus conducing greatly to the parallelism of the thread. If the end is not undercut it is practically almost impossible to cut a parallel hole with a hand comb-screw tool. It will be readily understood that, in order to make proper fitting chucks, absolute parallelism of the threads, both in the lathe-nose and in the chucks, is of paramount importance. The sections of chucks show how the thread should be made, being the sectional view of a chuck cut in two diametrically. At the extreme depth of the hole is shown the undercut groove to the full size of the thread.

When the comb-chaser is used, its first tooth will always be felt to pass over the solid metal into the space. Thus every trip will be made all along the thread and not be discontinued at irregular places more or less distant from the bottom, thereby making, of necessity, a conical thread or rather one which is not cut out to a sufficient depth at the bottom part of the hole. The first turn of the thread is shown turned away in all the cuts. This is the best plan to ensure the chuck screwing right home to its shoulder, as it is not possible to get

the thread on the mandrel-nose fully cut up against its shoulder.

Sometimes the nose has a groove turned in it close against the shoulder, to allow the chucks to screw up without having the first thread removed. But this is not a commendable system, as it weakens the nose very much at its normally weakest place, which is both undesirable and unnecessary ; whereas the removal of the first thread in the chuck has no detrimental effect whatever, and does not practically weaken the chuck in the least.

To return to the screwing process. Having cut out the groove at the back, proceed to start the thread with the small entry tap. Bring the back centre up to support the tail-end of the tap, and ensure its being square with the hole. Hold the square with a spanner or wrench, which may rest against the bed of the lathe to prevent rotation of the tap, and with one hand on the lathe pulley draw it round, the other hand being kept on the back centre winch, so as to keep the point up to its bearing against the tap. By this means the tap will easily be run in to the bottom of the hole, the usual lubricants being used as in ordinary tapping ; and on withdrawing the tap there will be a perfectly true spiral thread traced on the inside of the hole. This thread will not be deep, but if the points of the thread on the tap exactly match the points of the teeth of the comb-screw tool, it will be found comparatively easy to follow the shallow

spiral with the hand tool, and cut out the thread as true as it was originated by the tap.

Details of the use of the comb-chaser are given in another chapter, and we will suppose that the thread inside the chuck has been cut out fully by that tool. There should, however, still be an appreciable amount to be removed by the tap itself, otherwise there will be no certainty of the fit being accurate. By accurate, a tight fit is not what is meant, but simply a fit which does not allow an unconscionable amount of shake, or permit of a quantity of extraneous dirt being collected in the threads, without causing inconvenience. The tap is used expressly to ensure each chuck being exactly alike in the thread; and of course its object would be defeated if the hole was made too large by the comb-chaser. It seems superfluous to add that the tap must be made of the exact size to tap the chucks to fit the lathe nose exactly. Having completed the thread so far, the first turn or so must be cut away to allow the chuck to shoulder up properly. The best plan is to bore out the thread to a depth of about $\frac{1}{8}$ inch, the full size of the exterior diameter. This can be done with a tool in the slide-rest, and then just taking off the sharp edges with a round-nosed tool by hand. An ordinary chamfer made by means of a graver, cut in at an acute angle, is a very generally adopted method, but not so good as the one first indicated. The thread in the chuck being now finished, it may be screwed on to

the nose of the lathe, and if it shoulders up fair, and the nose and shoulder of the lathe are true, the thread and shoulder face of the chuck, in which the casting is fixed, will run perfectly true also; but if the nose is "drunken," or the shoulder out of flat, this will not be the case. Unfortunately the generality of lathe-noses are defective—either drunken, crooked, or out of true—and the same may be said of the shoulders. These defects make the labour of fitting chucks far more tedious and unsatisfactory, as it is impossible to make a true thread and true shoulder match an untrue mandrel and fit; and the difficulty is only increased if *both* chuck and lathe are untrue. The only plan open for fitting an untrue nose is to make the chucks considerably larger in the thread than would be a "fitting" size, and thus by allowing plenty of shake the chuck, mandrel, and shoulder are brought together, forming a "general" bearing, which will be of a more or less lasting character, according to the magnitude of the error in the nose. When fitted, the chuck should go right up against the shoulder, and take an equal bearing all round. This will easily be seen on examining the chuck which will show any points of specially hard contact. Some people advise that these—what they term "high parts" of the chuck—should be filed down so as to allow the other parts to come into contact; but this is an erroneous idea if the chuck is turned flat on its shoulder bed. The proper way would be to correct the lathe nose itself; but this is a job few

would care to undertake, as it involves processes but little used in the general run of workshops.

The method adopted will be dependent on the chief source of error, whether the shoulder of the nose or the thread itself is most out of true; also if the mandrel is hard—*i.e.* too hard to be turned by a graver—or soft enough to be turned true with a hard tool. If the shoulder is out of flat and quite hard, it is best made true by means of a copper lap, running in a drilling spindle and fed with emery. This is driven very rapidly, and the mandrel is revolved at the same time very slowly; thus the high points are soon ground down to a common level and the face of the shoulder made flat and square. This operation will throw all previously fitted chucks out of flat entirely, and they will all have to be turned up true afresh. Some chucks will not stand this, and would therefore be quite useless. If there is already a quantity of chucks fitted to the lathe, it is not very advisable to attempt any correction of the nose; but if a lot of new chucks are to be made, by all means start operations by truing the shoulder and thread as far as possible, making the thread parallel and reducing the length, if necessary, to equal the diameter.

CHAPTER VIII.

VARIOUS USEFUL CHUCKS DESCRIBED.

The point-chuck—The prong-chuck—Different forms of drill-chucks—Taper screw-chucks—Face-chucks—Cup-chucks with three and four screws—Die-chucks with single pairs and movable dies—The four-jaw face-chuck.

THE various chucks used on the lathe are of almost endless variety, and it is here only intended to describe those which are the most useful of the several classes into which they are divided, according to the special uses to which they are most applicable. Appended to the descriptions which follow is a brief indication of the purposes for which the chucks are used. Some chucks are almost duplicates of others that are shown, it being sometimes useful to have a choice of tools for doing some particular work. From the illustrations and details accompanying them, the construction will be made sufficiently explicit to enable the turner to make such chucks for his own use. It is advisable to here point out that chucks will only run absolutely true on one mandrel-nose; they cannot be used indifferently on other lathes if truth is required. For this reason it is obvious that turners

must make their own chucks, or, at least, that these must be turned on the lathe to which they belong.

The chucks that are commonly supplied with a plain lathe by the maker will occupy the first place. They comprise a point-chuck, a prong-chuck, a drill-chuck, and a taper screw-chuck. These will now be described in the order given. These four

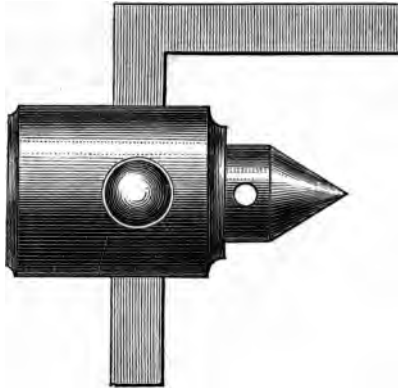


Fig. 9.—Elevation of Point-Chuck.

chucks, at least, should be fitted to the lathe before attempting to undertake any job in the shape of general turning; they are each one useful, and when the range of work is of any extent will require to be supplemented by the addition of other chucks described further on.

The point-chuck, also called a driver, a running-centre, or a take-about-chuck, is shown in Figs. 9 and 10; it is used for metal rods always supported

at the other end by the back-centre. Work turned by this chuck is said to be turned between centres, and on account of the facility with which work can be mounted on the lathe in this manner it is the

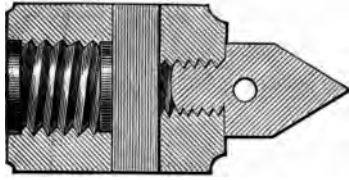


Fig. 10.—Section of Point-Chuck.

one always adopted when the nature of the object to be turned allows it. The point shown in the chuck can be replaced by one hollowed out to receive

a pointed piece of work. This form, called a female centre, is used by clockmakers, who turn all their arbors with pointed ends. Engineers use the male centre as shown, and centre their work with a centre-punch. Large lathes usually have the centres fitted into the mandrel itself, which is drilled up for that purpose; this keeps the centre near to the bearing, an advantage that will be appreciated from what has been said on page 20. In this case a circular disc of metal, invariably cast iron, is screwed on to the mandrel-nose, and has a short, straight driving-pin screwed into it to catch the tail of the carrier. Usually two or more holes are drilled and tapped for the pin, at different radial distances, so that it may be shifted to suit the work. A modification of this form is used instead of the one here illustrated, and forms a stronger chuck, and easier to make, though it is not so generally employed.

The prong-chuck is used for turning wood supported by the back-centre. This chuck is illustrated in Fig. 11, and is made with the central pip turned true, and the two edges are bevelled from the back only, so as to make them like a carpenter's chisel; thus the two edges do not form a straight diametrical line, as they would if bevelled from both sides. This latter shape is more likely to split the wood, and besides does not hold so firmly as the form first described. The central pip keeps the work central, and the prongs carry it round. The central point must run true, so that if removed the work can be replaced true. To use the prong-chuck the work is put with its centre against the point, and by blows of a mallet driven on sufficiently for the prongs to enter the wood. The poppit-head is then brought up and the centre-point screwed into the centre of the work to support it. Several modifications of the prong-chuck are to be met with, but the form illustrated is the best.



Fig. 11.—Elevation of Prong-Chuck.

The drill-chuck generally supplied is like Fig. 12, without the nozzle, with a steel clamping screw to bite the drills. This is a very good form for large-size drills, say those made from half-inch stuff and upwards, but for facility in changing the drills it is better to use chucks shaped like Fig. 13.

Separate nozzles may be made to fit in the plain chuck first figured, but these are shown as solid pieces of steel driven into cast-iron chucks, so as to be complete in themselves, and consequently

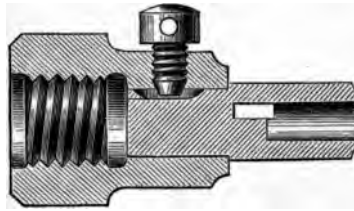


Fig. 12.—Section of Drill-Chuck, with Clamping Screw and Parallel Nozzle.

stronger and less liable to run out of true. The first nozzle is bored with a parallel hole, and the cross mortice is made at the bottom of the hole, all on one side of the diameter. The drills are fitted parallel into the hole, and have half the diameter filed off at the end to form a piece to project into the mortice hole. In some cases the mortice is cut in the form of a slot from the side, which saves trouble, but weakens

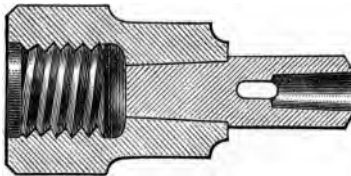


Fig. 13.—Section of Drill-Chuck, with Taper Nozzle.

the chuck by depriving it of the support afforded by the metal shown above the mortice in the figure. The second nozzle is bored out with a taper D-bit, and has the mortice hole cut diametrically across. The drills are fitted tapering, and have flats filed at the end on diametrically opposite sides, leaving a flat piece to enter the mortice hole, where it cannot turn. With the

taper socket the drills are wedged in quite tight, and cannot come out of the chuck, as they sometimes do with parallel fitting. For this reason it is to be preferred; another advantage is that the centre of the drill is preserved. In order to get the drills out it is necessary to use a lever behind the tail of the drill, which projects into the mortice hole. Several drill-chucks, or, at least, nozzles, are wanted to suit different-sized drills, though usually only one is supplied with the lathe. Drill-chucks having a square hole are sometimes used, but, except that they carry any of the square-shanked drills and bits belonging to the carpenter's brace, they are not to be recommended. Though it is as well to point out that the tools fitted to a brace are intended to cut the same way as lathe-cutters, and consequently may be used in the lathe in the ordinary way.

The taper screw-chuck shown in Fig. 14 is useful for the purpose of turning wood used plankwise, if a central hole may be made for the screw to enter. Any wooden disc may be fitted to this chuck by boring a hole for the central screw and screwing it into the wood; this on coming against the face of the chuck will lie fairly flat, and the edge and face



Fig. 14.—Elevation of Taper Screw-Chuck.

may be turned with facility. To hold large discs of beech for chucking work to the taper screw-chuck will be found very useful. The screw itself is made of steel, and ought to be cut with a specially-made chaser, for if the ordinary comb screw-tool is used to cut the cone the thread will be inclined very much, and its hold on the material considerably reduced.

In addition to those already named, plain wooden chucks are generally fitted by the turner himself; these are simply pieces of hard wood, box being much used, screwed to the lathe-nose, as has been described in the previous chapter. They are employed principally to hold work which has been turned true, and may be held by its edge in a recess cut in the face of the wood. For large work beech plank screwed on the taper screw-chuck and turned true is used. The ease with which partially-finished work may be chucked perfectly true, and firmly held without damage, is the great recommendation to wood chucks; also, they are inexpensive, but in use are continually being turned away to fit fresh work, and consequently are lost in shavings. Chalk rubbed on to the edge of the wood which is to hold the work materially increases its bite. As the nose-thread in a wood chuck is liable to be torn out they are often fitted on to a metal flange somewhat resembling Fig. 14, the wood being secured to it by ordinary joiners' screws put through holes in the flange.

A face-chuck is very useful for holding many

kinds of work of irregular form that sometimes cannot be chucked in any other way. The face-chuck, also called face-plate, is usually of cast iron, and as large as the lathe will allow; some have numerous holes drilled in them, through which bolts pass to hold the work; in others these holes are all tapped, and the bolts screw into them. Some have radial slots, allowing the bolts to slide to any required distance from the centre. Dogs and clamps are used with the face-plate, and the work is laid on it and secured by clamping to its face, which must always run perfectly true or flat. Without back-gearing it will be found very difficult to turn up the surface of a cast-iron chuck the entire diameter that the lathe will take, but the face-chuck is so useful for many and indispensable for some purposes that one should always be fitted to a lathe intended for general engineering work. Castings for such chucks are sold by many founders, it being only necessary to specify the diameter required when ordering. The clamps used for holding work to face-chucks should be packed up at the back end slightly higher than where they come in contact with the work, or they have a tendency to force the work away from the holding-down bolt. In cases where the turning of an object subjects it to much strain a stop must be fixed to the face of the chuck to prevent the work turning. The clamps are not adapted for this purpose, and are only intended to hold the work against the surface-plate. When the weight of the

objects is much out of balance a counterpoise weight must be bolted on to the chuck; this will check the vibration which in unbalanced work precludes the possibility of satisfactory results.

Cup-chucks fitted with screws to clip the work are employed principally to hold short objects, such as nuts or short rods which are too large to

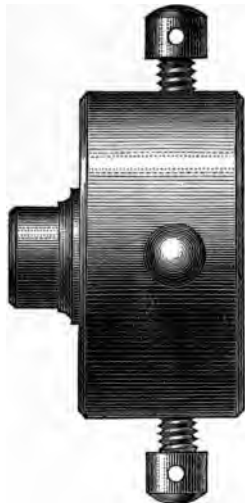


Fig. 15.—Elevation of Cup-Chuck.

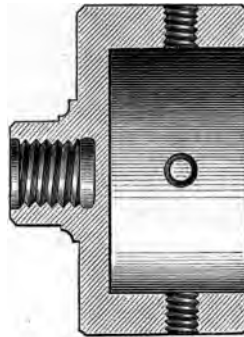


Fig. 16.—Section of Cup-Chuck.

go in a grip-chuck. Cup-chucks may be of from 1 to 6 inches internal diameter, and are fitted with three, four, six, or eight screws. The woodcut, Fig. 15, shows one having four screws; if only three were used they would be spaced equidistant, and the work is more easily adjusted if held at three points of contact. Six and eight screws are arranged in two circles, and the screws in one are placed

intermediate to those in the other. The object to be held in the chuck is gripped by the points of the screws, and these can each be screwed in as required to centre the work. The projecting screws are often apt to be in the way and cause damage, and their points badly mark the work; these circumstances are somewhat of a drawback to the use of screw cup-chucks. The construction of cup-

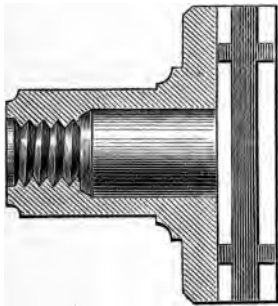


Fig. 17.—Section of Die-Chuck.

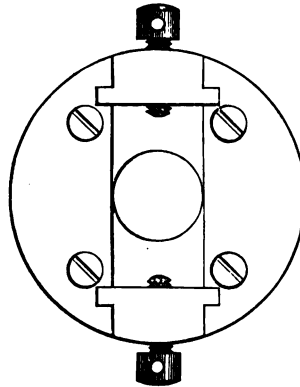


Fig. 18.—Front end of Die-Chuck.

chucks is best shown by Fig. 16, a sectional view of Fig. 15.

Grip-chucks are used for holding all kinds of rod-metal, and one with changeable dies, shown in Figs. 17 and 18, is a most serviceable addition to any lathe, and almost indispensable for many things. Though there is more work in its manufacture than in those with only one pair of dies, yet the extra labour is more than compensated for by the convenience and extra range of this chuck. The body

nearly the full size that the lathe will carry. For all work beyond the range of the previously described die-chuck the jaw-chuck with its four jaws moved by independent screws comes in useful, often serving advantageously in the place of the face-plate. A minute description would occupy more space

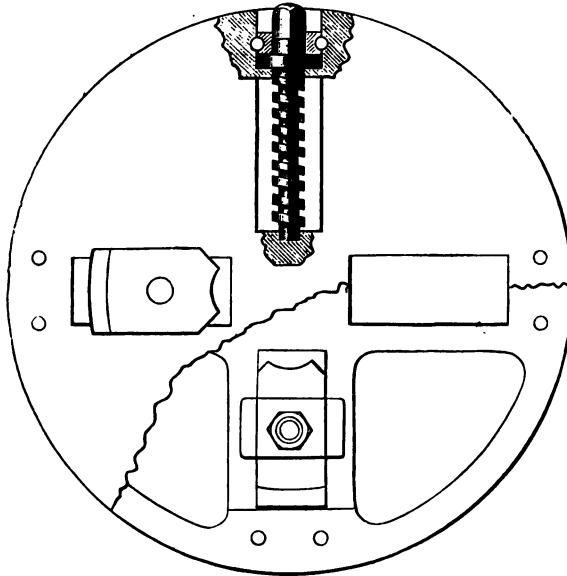


Fig. 20.—Four-Jaw-Chuck: top, Screw in elevation, Chuck in section; left, front of a Jaw; right, Slot without Jaw; bottom, rear side of Chuck, showing Fillets and a Jaw.

than can be here allowed, but from the drawing, which shows details of the principal fittings, the construction will be sufficiently clear to answer the purpose of a working drawing in the hands of a practical man. The diameter of this chuck should be as large as possible, and the jaws must not be too

long, or there will be a certain size that cannot be gripped, because it is too small for the stepped part, and too large for the points when opened to their fullest. The jaws, one of which is shown in section at Fig. 21, are made from solid forgings, and must be properly case-hardened.

It is most important that the washers placed on the back of the dies should bear against the casting, or the dies themselves will be twisted upwards directly they are brought against anything to be held.

With these principal chucks we must content ourselves; they will be found equal to dealing with most work usually found, and modifications of the various kinds will suggest themselves should occasion require.

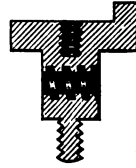


Fig. 21.—Section of Dog belonging to Four-Jaw-Chuck.

CHAPTER IX.

SLIDE-RESTS.

Their advantages, various forms—Fitting up slide-rests, ornamental and plain—Tool-holders—Self-acting slide-rests—The leading screws and material for nuts—The bearings of the screws—Height of a rest—Adjusting slide-rests—Spherical rests.

THE slide-rest may be fitted to any lathe and at once greatly enlarges the scope of the tool, as by its aid much work, quite impossible to execute by hand, may be turned easily. Material that is very much out of truth, through being chucked eccentrically or being of irregular form, only reaches the turning tool at intermittent times, and under these conditions it is not easy to hold a tool by hand, so that it acts properly. But in the properly fixed slide-rest a tool is held perfectly rigid and acts equally well on work already made perfectly true, or in turning down only the extreme angles of a square rod chucked between the centres, this latter operation being almost beyond the reach of a hand turner. All work which has a break in the continuity of its cylindrical surface is difficult to turn with hand tools, unless it can be revolved at a very great speed, as may be proved by trying to

true up the teeth of a coarse pitched cast-iron wheel with a graver. This is intended only as an instance, as such a job would be executed by means of a file resting against a bar held in the slide-rest. In turning a parallel cylinder by hand, considerable care and constant gauging is requisite to reduce the material sufficiently and yet guard against cutting too deep at some part. With a slide-rest there is no need of such care, for when once properly adjusted a perfectly true and parallel cylinder or cone is produced by simply feeding the tool up to the work, and even this is often done automatically.

Slide-rests are of different forms to suit special purposes. That most generally used for metal turning or miscellaneous work consists of one slide at right angles to the bed and fixed to it by a bolt at any suitable place, as in the hand-rest. On the saddle of this slide another one is fitted at right angles to the lower one, and on its saddle is an arrangement for holding the tools used for turning.

Ornamental slide-rests are made differently. They usually have one long slide which has a stem at its centre and fits into a sole like the T-rest sockets; this allows of the rest being placed at any desired angle with the line of centres or parallel to the face-plate. It will be noticed that when this main slide is in its two positions the end which takes the winch-handle is reversed, and the leading screw should therefore have a corresponding projection

at each end, so as to allow the handle to be placed indiscriminately on either.

It is desirable to fit the handles so that they may be removed from one end to the other without trouble; a plain square fitting is the best, made very slightly tapering, so that the handle will wedge on tight enough to remain during manipulation, as it is excessively annoying to have the handle continually dropping off through the vibration of the rest when using overhead gear. A plain milled head fitted to the square is very handy for actuating the screw in special work, and if the screws of both top and bottom slide have their terminations squared off to the same gauge, as they should be, the handles become interchangeable.

The bottom slide, which is the longest, should allow the saddle to travel along a distance about equal to the diameter of the largest face-plate the lathe will carry—that is, double the height of centres. The sole of the rest must be fitted to slide at right angles to the lathe-bed, so that the slide may be placed at any desired distance from the centres, according to the diameter of the work to be operated upon. By these means the top slide may be very short, it being merely required to set in the cut of the tool after it has been placed roughly in position and the slide-rest set fast by means of the main bolt.

There are several ways of fitting the sole to slide squarely; it may be planed up true, and run between two bearers of a saddle fitted to the lathe-

bed, but the most simple plan is to have the dovetail groove planed quite true and fit a piece of iron to it exactly, the continuation of this iron below the under surface of the sole-plate being fitted to the lathe-bed between the bearers. Each piece of fitting should be as long as convenient to afford greater bearing surface and consequently accuracy of adjustment. The whole piece, which may be either of cast or wrought iron, would appear like a cross when seen from above, and the two cross pieces, being on different planes, showing like a T when seen from the side.

The rest may be shifted with the greatest ease, when the bottom of the sole has a dovetail groove, as when the bolt is slackened the piece would run perfectly free, the sole being drawn square with the bed on tightening down. With a T-shaped groove it would be necessary to fit the sliding piece in a rectangular slot, which, besides being a far more difficult job, would not allow the freedom in shifting as above mentioned.

The top slide of an ornamental rest is usually actuated with a lever instead of a screw, which enables the operator to throw the tools in and out of cut more quickly. A leading screw is generally fitted also, which may be used if occasion requires. For ornamental work, stops, to confine the travel of the slides, are requisite to ensure the equality in length of longitudinal grooves and flutings. Though it is possible to execute work with tolerable precision without the aid of these stops, yet they

become almost indispensable to insure absolute accuracy, and are sure preventives against going too far. The general method of holding tools in an ornamental rest is in a rectangular slot to which they are accurately fitted.

It is comparatively seldom that one finds two slide-rests—one for plain metal-turning and the other for ornamentation—belonging to the same lathe, one rest being usually so modified as to suit the requirements of the general run of work.

Tool-holders for clamping the tools in the slide-rests are made in various shapes. The form used in ornamental rests is mentioned elsewhere. For heavy work the chief consideration is that the tools will be held firm, and that they may be fixed in any position on the rest for boring or turning the outside of a cylinder and at any intermediate angle. This is best secured by having the tool-holder to revolve freely on a central stud, or, as is often done, the holder is itself a stud which turns freely in the top plate and has a transverse mortice for the tool to pass through; the single screw, which clamps the tool, also fixes this stud at the same time. It is advisable to make the tool-holder so that it will take a square bar, the centre of which will come to the height of the lathe centres. The importance of this will be better understood on reference to the drilling spindle described in another chapter.

It is essential for all purposes that the rest should be perfectly rigid under ordinary usage, and that the slides should work quite parallel and

true with the lathe centres when the rest is tightened down on the bed. There must be a fair range of traverse in the slides, so as to allow the tool to be applied to an average surface of work without the necessity of shifting the entire rest by moving it on the lathe-bed. For ornamental work, with the drilling apparatus, fly-cutters, and such tools in the slide-rest, and the division plate in use, it is very convenient, and in fact almost necessary, to be able to throw the tool in and out of cut readily, and quickly to replace it with accuracy to the same setting for the next cut ; a lever handle, as before mentioned, is indispensable for this purpose.

In metal-turning or plain work this lever becomes highly objectionable, as it necessitates the undivided attention of one hand at a time when both may be required to actuate the lathe or perform some work in other ways. A leading screw working in a nut and having a fixed lateral bearing therefore becomes requisite in order to afford greater facility in handling. Consistent with the primary consideration—rigidity—a slide-rest may be made as light as possible for elegance in appearance.

The accuracy of the work produced by a slide-rest will depend very much on the way in which this is fitted, and it is therefore necessary that rests should be properly constructed, with all the parts adjusted to each other, the slides level with the lathe-centres and fitting evenly the whole length of

their travel without shake ; the strength of the parts being so proportioned that the whole structure will be quite rigid.

In a self-acting screw-cutting lathe the slide-rest is fitted to slide on the bed itself, and is moved along by the leading screw of the lathe usually extending the whole length of the bed, the nut in which this engages being split and actuated by a cam under the control of the turner, who can disengage the nut from the screw at any time instantaneously, and so arrest the motion of the rest along the bed without stopping the lathe. Such a rest fitting on a dovetail slide cannot be removed from the bed entirely, but may be slid to any convenient place along its length.

The screws used to actuate the slides are called leading screws ; there is no rule as to their size and pitch, and right and left-handed threads are equally effective ; so also square and angular threads may be used indifferently. For coarse pitches of small diameter, square threads make a stronger screw than angular ones. For rate of thread a good proportion is ten to the inch for a 5-inch lathe. Relative to the adoption of right and left-handed screws there seems to be much diversity of opinion, and makers do not seem to agree on the subject. Some put both screws right-handed, some, though less often, put left-handed, and some, amongst whom are numbered the best, put one left and one right-handed leading screw to the slide-rest. The only object in having them this last way is to afford the

operator the convenience of producing similar results by similar motions of the handles.

By standing at a slide-rest and making the experiment, it will be found that on turning the two handles in the same direction the motion is really in opposite directions. Supposing both handles of the slide-rests to be in their highest position, on pushing from you the one which is parallel the screw is turned towards the right; when the other handle at right angles to the bed is pushed away the screw is turned towards the left, so that in turning the two handles away from you they really turn in opposite directions.

Therefore, in order to make the same apparent motion produce the same actual effect, a left-handed screw is put in for the top slide, while a right-handed one is used for the bottom one; and though no absolute advantage is gained, yet it is very convenient. In all cases the back centre should be actuated by a screw of the same rake as the one in the top slide, so that motion of the handles in the same direction will produce like results. When the top of the slide-rest and the poppit barrel are actuated by reverse screws, the effect is very embarrassing, so that these two screws had best correspond, whether they be right or left.

The nuts for leading screws may be of wrought iron, brass, gun metal, or almost anything similar; gun metal works more smoothly, and if attention is paid to lubrication will last as long as required. The nuts need not be screwed on to the under

sides of the saddles; they may be just let into a hole drilled for the purpose, a round tail being turned on each nut to fit. The lateral motion of the leading screws has to be prevented; they are usually fitted with bearings in the respective slide castings, and to stop endway movement of the screws when actuating the saddles several methods are made use of, each having its special claims.

One good plan is to reduce the diameter of the end of the screw for a length just exceeding the thickness of the casting, and fit this part in the hole, allowing it to project say the eighth of an inch; a steel washer has to be fitted on to the projecting part so that it cannot turn round independently of the screw. A small hole is drilled up the centre of the screw end; this hole is tapped, and a screw fitted with a large head, sufficient to take a good bearing against the washer, and so keep it in its place, that is, firm against the casting. When a plate is put on, as described lower down, to take the thrust of the screw, the boss cannot well be used as a divided head, which is often very desirable, and this is why a nut on the rear end of the screw is preferable. In another plan a boss is left at the handle end of the screw; this bears against the casting, and at the other end a nut is screwed with a washer fitted on hexagonally, and both are let into a countersunk hole in the casting, preventing the screw from being withdrawn. The boss on the screw may be made to go into a countersink with its thrust bearing against a small plate held

on by two screws ; the other end of the leading screw is turned down to form a pivot the size of the diameter of the bottom of the thread, and fits into the hole in the casting.

Conical bearings are sometimes made to the screw, but the wear is so very slight that there is no need for this. Providing the screw is carefully and well fitted in the first instance, it will last out the other parts of the rest, and therefore conical bearings may be considered useless. The motion of the screw without moving the saddle, caused by slackness in the fittings of the screw in its bearings and in the nut, called back lash, does not detract from the slide-rest's utility when applied to its legitimate purpose, though this back lash is often a source of much trouble and annoyance. But it cannot possibly be eliminated entirely without the use of double screws, or some such costly contrivance.

For turning cones, the upper slide of the compound slide-rest turns so that it may be placed at an angle with the bed, some rests being arranged so that the top side may swivel all round, and others have only a small angular motion, which is, however, in most cases, sufficient, as cones are not generally required very obtuse. The ways in which the angular motion of the side is obtained are these :—The best plan, which allows the top slide to be swung round all the way from right angles to parallel with the bottom side, is managed by turning a T-shaped groove in the thickness of the

saddle of the bottom slide into which the heads of the two bolts fit, and consequently the top slide may swivel round entirely. The more general plan is to screw the bolts into a hole in the under saddle, and cut a circular slot on each side of the circular base plate of the upper slide, extending as far as the sides of the slide will allow, and in this case the length of the curvilinear slots determines the amount of the angular motion of the top slide.

The first-mentioned plan is, of course, the better, but it involves more work, and turning the T-groove requires a great deal more care to ensure the depth being equal on both sides so that the heads of the bolts will take a fair bearing. It is seldom required to set over the top slide more than 30° for ordinary work, and the second plan of slots allows this. Being easier of construction it is consequently the more generally adopted. The top slide swivels on a steel pin, driven tightly into a hole in one casting (it is immaterial which), the other casting having a hole carefully fitted to the projecting piece of the pin, which forms a pivot at the centre of motion. The fitting of this pin must be accurate, without shake, otherwise no dependence can be placed on the angular setting as shown by the index which is fitted up, as described further on, to show the angle at which the rest is set.

The best height for the top plate of the rest, on which the turning tools fix, will depend on the size of steel generally employed for these tools; the usual size of steel should lie wholly beneath the

centres. In order to determine the point, the most suitable size of which to make the tools must be decided. For a 5 inch lathe, square cast steel $\frac{1}{2}$ inch or $\frac{5}{8}$ inch suits very well ; tools for light work and fine cuts to be made from the smaller size, and those for roughing down and heavy work generally to be made from the $\frac{5}{8}$ -inch bar. In such a case the tools made from the larger stuff will be all the better for having their ends forged with the point or cutting edge low down, and if this is done to the extent of $\frac{1}{8}$ inch all the tools will be $\frac{1}{2}$ inch above the top of the slide-rest. It is easy to pack up tools by placing strips of metal, such as tin plate, under them, and so adjust the cutting edge to its precise point, that is, on the line of centres. Allowing $\frac{1}{16}$ inch for this, the top saddle will be $\frac{9}{16}$ inch below the centres ; this is the correct distance for a 5-inch lathe.

When a slide-rest is put to a lathe, the first object is to get it fitted quite true with the line of centres, and the bottom slide must have attention first. The leading screw is removed from the lower slide and the face-plate screwed on the lathe-nose. A centre punch or stiff scribing point is wedged into a hole near the edge of the face-plate, and a flat pointed tool is fixed in the slide-rest. When the lower saddle is at the two extreme ends of its slide, and the point in the face-plate at the near and far side of the lathe, the tool in the rest must just touch it, and will thus show whether the slide is perfectly parallel with the face-plate and at right

angles with the bed. Should the slide be at an angle, the contact of the points will at once show it, and the bottom of the rest must be filed to bring it right. The lower slide finished, the upper one is next treated in a similar manner, using a bar between the centres with a projecting point in it instead of the face-plate.

When the two slides are adjusted to the exact position for turning parallel and flat respectively, a legible mark should be made to enable the top slide to be reset at precisely the same angle after it has been shifted for conical turning. A scale and index point to show the angular motion of the slide are sometimes put, and will be found very convenient. The divisions should always represent degrees, that is, the 360th part of a circle, or parts of degrees. Then cones tapering to the amount required can be turned by setting over the slide-rest to the necessary distance, and there will be no need for callipering. The advantages of an index will best be appreciated when it is required to turn a cone and a hole for it to fit in. The large end of the cone will nearly always be towards the mandrel end, and the hole will be reversed, that is, with its largest end away from the mandrel. Consequently the slide-rest will have to be set at reversed angles to turn the hole and the plug; without a scale it will be most difficult to set the rest at angles which correspond precisely. In making such an index the divisions are usually marked upon the saddle of the slide, and the point

is fixed by a couple of screws to the circular base-plate of the top slide. This point may be itself fixed to read correctly for turning parallel with the index at 0° . The best plan for ease in reading is to make the index with a flat end about $\frac{1}{4}$ inch wide, with a line marked in the centre to read against the scale lines, as it is much easier to distinguish the continuity of a line than the position of a pointer with respect to a line.

Spherical slide-rests are sometimes used for producing, but chiefly for ornamenting spherical surfaces; they are seldom met with except on ornamental lathes of the highest class used by amateur turners. The circular motion is produced by fitting a worm wheel and tangent screw to the base of the slide, which is then turned round by means of a handle in precisely the same direction as it would be for conical turning. There are many other additions necessary for the proper use of a spherical slide-rest, and owing to its complicated construction further details would be of little use unless an elaborate description was given, and that would not be within the scope of the present treatise.

The slide-rest is the receptacle for various kinds of apparatus used for wheel-cutting and for shaping material which is held by the mandrel; some of these are described in other chapters. The tools proper consist of square bars of steel having one and sometimes both ends formed into cutters; these solid tools are used for roughing down work and the general run of turning. For special cutters

shaped for particular purposes, or those used in certain ways, tools called slide-rest cutter-bars are used. These are bars similar to the ordinary tools with ends shaped to hold small cutters, which may be made with much less trouble than the solid tools mentioned above.

A slide-rest should be strong enough at all parts not merely to resist absolute breakage but to maintain perfect rigidity under the wear and tear of a heavy cut. Several items have to be taken into consideration when judging the strength, or rather inflexibility, of a rest. A certain amount of metal is requisite to make a solid tool, but much more depends on the way in which it is fashioned than appears to be generally understood, judging from the clumsy designs which are sometimes made. Good fitting is also essential to the main object in view. A carefully fitted slide-rest, of neat and elegant design, will stand more hard wear and tear than half-a-dozen of some of the clumsy, heavy, badly-proportioned tools thrown in the market by second-rate manufacturers.

CHAPTER X.

SLIDE-REST TOOLS.

Angles suited for various materials—Useful tools for general purposes
—Cranked tools, knife tools, parting tools, spring tools—Tools
for inside turning—Correct height and adjustment necessary.

SLIDE-rest tools are of numerous forms, some the result of peculiar individual fancy, others made to meet the exigencies of the work they have to perform. In the chapter treating of cutter-bars much information applicable to solid tools will be found, and these latter it will be seen, by what is there stated, are to a large extent superseded by cutter-bars from motives of economy. The solid tools are, however, very much used, and in small workshops they generally do the whole of the work, cutter-bars being probably not introduced from a notion that their prime cost would not be warranted by the work that would be exacted from them, or that the economy would not be commensurate with the cost. Solid tools are usually made of square steel, though that of varying rectangular section is sometimes used, without any apparent object, however, unless in the case of tools of particularly broad or narrow width. Cast steel

of special quality should be always used, as the ordinary material is not adapted to stand the work required of a slide-rest tool.

The size of the steel used will be determined according to the height of the slide-rest plate, as explained on page 113; the length used is optional, so long as it is sufficient to leave enough shank to be clamped under the tool-holder. Some tools are made with each end formed into a cutter, and thus the number of available cutting edges is doubled without increasing the number of tools. This plan is one that finds little favour, though in some forms of tool nothing can be said against it. For example, screw tools for the slide-rest are always made with the comb at both ends, they also being usable either side up. Tools that are cranked, if made double ended, must have the cranks at right angles or on opposite sides, as otherwise the tool cannot be laid flat on the top of the slide-rest.

The angles best suited for the particular material to be operated upon are most desirable in slide-rest tools, and after having had some experience with hand tools, more especially as applied to soft-wood turning, anent which some information is given in another chapter, the advantage of various angles will be appreciated. It will be understood that the cutting edge will penetrate best when it is thinnest; other considerations, however, prevent the adoption of this rule unreservedly; and for metal work tools are found to act best when the faces form the cutting edge at an

angle of from 60° to 90° . The face of the tool coming next to the work requires to be ground at a slight angle, leaving the point prominent to prevent the whole face touching the work, and so by the friction greatly increasing the labour of turning. When this requirement is satisfied the face should be as straight as possible, and 3° from the perpendicular suffices. This applies equally to tools with acute edges used on wood, though when we come

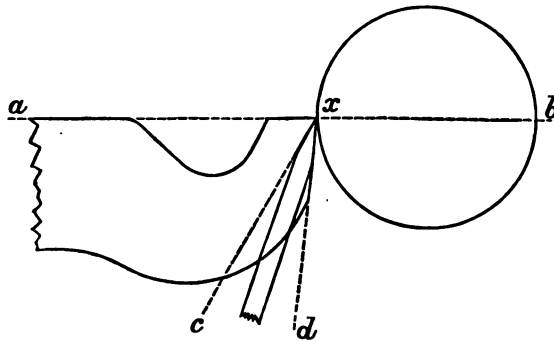


Fig. 22.—Angles of Turning Tools for Wood and Metal.

to knife edges the face of the tool itself usually rests against the work it has to cut and there is no angle of clearance.

Fig. 22 herewith shows tools correctly applied for cutting both wood and steel. By this it is seen that the slide-rest tool, with a strong cutting edge suited to dividing the cohesive metal, and the acute wood-turning chisel, each have the lower face angle placed in the same position with regard to the work. Therefore it is only the upper face

which wedges back and curls or breaks off the shaving that is altered agreeable to the different nature of the materials. The line of centres is shown dotted $a b$, and at precisely the height of this line should be the point of the tool fixed in the rest. Here it may be advisable to point out that tools must be packed up with parallel strips, otherwise the relative position of the angles is interfered with. The edge of the metal-turning tool is formed by the meeting of the faces $a x$ and $d x$; $a x$ being parallel with $a b$, and $d x$ 3° from the perpendicular, gives the angle of the point as 87° . This is the most obtuse angle usually employed, though for some purposes where a scraping action is required the top face is bevelled off downwards to make the edge even more blunt. The edge of the soft-wood chisel is formed by the meeting of the faces $c x$ and $d x$, enclosing 25° , still keeping the lower face situated precisely alike. The tools might be applied at any part of the circle even vertically above it, so long as the same relative position is maintained; but the slide-rest as ordinarily constructed necessitates the application of the tool on a level with the centres.

The following illustrations give the forms of slide-rest tools usually made for general purposes. Fig. 23 is a straightforward cranked tool for outside work, and is perhaps the most widely used of all. The form affords great strength and facility for grinding. The face forming the top is usually nearly triangular in section, though the

form at the inner side is determined by the shape of the forging, and this is sometimes made by flattening every angle of the square bar, thus leaving the point, when ground, diamond shaped. The front faces meet at an angle of about 90° or a trifle less, and the arris, which comes near the centre of the bar, is ground away, leaving a slight face of from $\frac{1}{32}$ to $\frac{1}{16}$ in. wide. This treatment applies to all slide-rest tools, for if the acute arris is presented to the work the edge becomes blunted immediately.

Fig. 24 shows a tool of somewhat similar form,

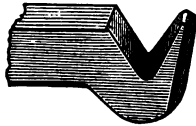


Fig. 23.—Straightforward Cranked Slide-rest Tool.

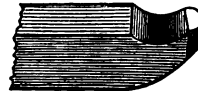


Fig. 24.—Round-nosed Straight-forward Tool.

though it may be made from a straight bar without necessitating forging. The face of the cutter is on a level with the top of the bar, and the metal behind it is removed to leave a hollow so that there is less left to grind. This tool is shown with a semicircular face edge, the form known as round-nosed, and it is a capital form for real work. The cranked tool described above may be ground to the same shape with advantage for certain work. The two tools, Figs. 23 and 24, are intended for roughing down plain surface or cylindrical work, and neither of them will cut into a sharp angle. Both work from right to left by preference, and the

top face is ground to a slight slope, to leave the left or leading edge a trifle higher. Both may be used in the reverse direction, though in that case the grinding ought to be done accordingly. When such tools are employed indiscriminately in either direction the top surface is ground off square, always, of course, sloping backwards to leave the extreme point highest, and this in accordance with the material to which it is applied.

A left-handed cranked tool is shown next, in Fig. 25. This is very much like Fig. 23, with the point bent sideways, towards the left, so that it is



Fig. 25. — Left-handed Cranked ; Slide-rest Tool.

brought beyond the level of the side of the tool shank; by this means the tool is available for use in the extreme corner of an angle where a cylinder joins a surface.

For example, in turning a bolt the front corner would be brought to work on the cylindrical part and the left corner would surface the head. The angle of this point is always less than a right angle, otherwise there would be no clearance and the whole breadth of the edge would be against the work, causing much unnecessary friction; an angle embracing about 80° will be found right. A corresponding tool bent to the opposite side, and called a right-handed cranked tool, is required for working in the reverse direction. Its form is precisely similar, so that no illustration is required; the point is to the right, as Fig. 25 is to the left.

Fig. 26 is a knife-edge side tool used for turning the end surface of a cylinder running between the centres, the form of this tool allowing it to go right up to the point of the poppit head, which the tools hitherto described are not adapted for. It will be seen that the end of the tool is forged to a narrow blade, and this is ground flat on its face side—that is the one represented as the furthest away in the illustration—but at an angle to clear, and the top and end are bevelled off to form cutting edges. A corresponding reversed tool for cutting on the left-hand surface of work is sometimes made, but it



Fig. 26.—Knife-edge Side Tool
for Slide-rest.



Fig. 27.—Slide-rest Parting
Tool for Metal.

will be readily understood that its use is of most rare occurrence for work on the lathe, though for planing of course both side tools are equally in requisition.

A parting tool for metal is shown in Fig. 27 ; in this the tool is forged with a thin central blade, as shown in the figure, and sometimes, when the width is very slight, it has a much greater depth, occasionally as much as an inch to give the centre tool support. The length of the blade should be somewhat proportionate to the work it has to do, and it would be absurd to use a blade long enough to part 3-inch stuff for that under an inch in

diameter. The tool is ground on both sides, tapering slightly to leave the top edge widest, and the blade must stand accurately upright to be clear of the sides of the groove that it cuts. The front end should be slightly the widest, so that the tool will not rub on its side edges as it proceeds through the work; if quite parallel it will act. Perfect straightness of the blade and its parallelism with the slide by which it is actuated in its forward path are essential. In short, the parting tool, when at work, must cut only with its narrow front edge, which is ground off square; its width may be from $\frac{1}{16}$ to $\frac{1}{8}$ inch, according to the size. Some further information on parting tools is given in the chapter on cutter-bars.

The next illustration shows another tool somewhat out of the usual form; it is called a spring tool, and its object is to present an edge that will to an extent give and take with the irregularities of the work, a property which, despite of all that may be said to the contrary, is a most undesirable one if the object of turning is to produce true cylinders. The form at Fig. 28 places the point of flexure much above the line of centres, and thus when any undue pressure is brought to bear on the edge of the tool it springs from the work, that is, if applied at the exact height of the centres. With a keen edge carefully whetted on an oilstone and a blunt angle, this tool forms a good planisher for long brass rods, but for the most part finishing is done with emery paper on a file. A piece of wood

wedged under the spring part will very materially strengthen the tool if less spring is wanted for a special job.

Inside turning with slide-rest tools often takes the place of boring, and *vice versa*, according to the ease with which the work to be operated upon may be mounted on the lathe. The tools used in the slide-rest for this purpose are very similar in their form, and Fig. 29 may be taken as a representative type. The dimensions are varied to suit the size of the hole in which the tool has to go, the size of the tool being generally restricted by that of the



Fig. 28.—Spring Turning Tool for Slide-rest.



Fig. 29.—Inside Turning Tool for Slide-rest.

hole. Referring to the illustration, it will be seen that the shank part is made cylindrical, the length being in accordance with the depth for which the tool is available, short tools being the most rigid, whilst deep holes necessitate the use of long tools. The cutting edge is formed by forging a lip towards the left side of the shank, and this is ground to the form shown, the top face being as nearly as possible on a level with the diametrical centre of the shank. Thus the tool can be introduced into the smallest hole allowable from its size, to cut at the correct height—*i.e.* at the line of centres. The tool shown is intended to cut inwards only, and round-

nosed edges formed like Fig. 24 are useful for cutting forwards and backwards through a thoroughfare hole, but are objectionable for holes that should have a flat bottom, from the circumstances explained in the comments on outside tools of the same form. With careful usage an inside tool may be employed of such slight dimensions that it will bore through a $\frac{1}{4}$ -inch hole 2 inches deep, and when the depth is not so great the diameter may be diminished to even less. The cylindrical part of the shaft of inside tools should be straight and level, though a slight taper is often no detriment and strengthens the tool materially. The projecting lip must be comparatively short, for all small tools or the leverage it affords will impair the cutting and spoil the truth of the boring even if it does not cause a breakage.

As has been shown, it is necessary to apply the tool to the work at a correct height, or else, no matter how good and well made it may be, the tool will fail to perform properly and to the best advantage. A gauge should be made, to be used every time a tool is fixed in the slide-rest, to test the height of its cutting point. A plain cylinder or piece of tube with the ends made perfectly flat, so that it will stand, and of such a length that when stood on a particular plane of the slide-rest, or on the lathe-bed itself, its upper surface is exactly level with the line of centres, is all that is necessary; and when the tool is finally clamped the height of its edge should be gauged. The height

is of course adjusted by means of strips of metal; thin bar iron and strips of tin of various thicknesses are best for this purpose, and the gauge is placed in position to afford a guide during this process. The correct adjustment cannot be too strongly urged, and a proper gauge is indispensable. If a tool does not work properly at the correct height, it is sure evidence that it is badly formed; and though a tool may be made to work apparently better above or below the centres, yet in such a position it is at a disadvantage, and should be put right according to the principles explained in this chapter.

CHAPTER XI.

SLIDE-REST CUTTER-BARS.

Advantages over solid tools—Some of those of most general application described—The graver used in the slide-rest—Straightforward tool, parting tool, internal tool—Saving effected by the use of cutter-bars.

IN many respects there are advantages in the use of cutter-bars as slide-rest tools in place of the usual form of solid bar steel, in which but a very small fraction of the metal is of any direct use so far as the cutter proper is concerned. The shank of the tool consists of solid metal of the same quality as is the point and cutting edges, and that is invariably the best, and consequently a costly kind. In cutter-bars one shank is used for any number of cutters, just as is the case with boring-bars, and thus only a small piece of metal has to be wrought, hardened, tempered, and ground when a cutter is required. A 6-inch bar of $\frac{5}{8}$ -inch square steel, weighing over half a pound, is replaced by an inch length of $\frac{1}{4}$ -inch square bar, weighing a quarter of an ounce. In making a dozen of such cutters the saving in metal, which would be a matter of using a quarter of a pound instead of 8 pounds, is only an

example of the saving in labour of making, and in the space the finished tools will occupy. As there are no direct advantages in the use of the more expensive tools, the use of cutter-bars has considerably increased. The saving effected by their use in large factories is enormous.

A cutter-bar must be essentially able to hold the cutter perfectly rigid, and so make it, for practical purposes, solid with the bar. In some badly contrived tools this, the chief desideratum, is neglected, and consequently such bars, being of little or no use, are discarded, and gain for cutter-bars, taken as a class, a bad reputation. That the cutters can be removed and replaced with ease and rapidity is, for convenience in use, an important feature, and to this is sometimes sacrificed the firm grip so essential. To the mechanic whose theoretical education has kept pace with his practical experience the arrangement of a thorough firm hold combined with a readily released grip will be easy. The wedge offers a ready and familiar example, and when this contrivance is constructed to be withdrawn easily it is, perhaps, the best of all clamping arrangements, but it requires solid points on which to take its bearings.

Clamping-screws are very good, and if there is sufficient material for a proper allowance of thread, both in respect to diameter and length, then a screw holds firm enough for all things. In cutter-bars, however, the proper size of these parts has usually to be reduced very much, and in many cases

the projecting head of a screw is objectionable, if not absolutely forbidden. Screws applied to draw parts together and hold the cutters in a vice-like grip are effective, and when allowable may be used with most satisfactory results. There are many ways in which cutters may be held, but they need not be discussed here; those named will suffice for the bars of which descriptions are to be given. The examples are offered as types on which it is quite possible to effect alterations and modifications to suit special requirements. The illustrations may serve as working drawings to those

desirous of constructing facsimile tools.



Fig. 30.—Slide-rest Cutter-bar, for holding Gravers.

The ordinary graver used for hand turning may be fixed in the slide-

rest by means of the holder shown in Fig. 30, which gives a sectional and top view of the arrangement. In this case the cutter-bar consists of two strips of metal with an angular groove running lengthwise, into which the graver fits. The sides of this groove are inclined so as to bring the tool to the best position for cutting, which may be best seen in the sectional view. The angles are 60° and 30° respectively, making together a right angle fitting the square tool. The two halves of the bar do not quite come into contact; they, however, take a fair bearing on the tool, and are so kept sufficiently rigid for all practical purposes. In making a bar of this description a piece of metal of double the intended

length, and in section twice as wide as thick, is selected. On one side of this the angular groove is cut from end to end; the bar is then divided in the middle and the two halves laid one over the other, as shown in the drawing. Though the ordinary graver is perfectly suited for use in this bar, yet practically it is more economical to use a piece of square bar steel properly hardened and tempered, both ends of which may be ground for cutting. The angle which forms the point should be somewhat rounded off to make the tool stand better. This forms an excellent tool for roughing-down purposes; and a trial of its capabilities, which may be easily made by using hard wood for the clamping-bar, generally leads to the ultimate adoption of this form of cutter-bar for the purposes to which it is specially suited.

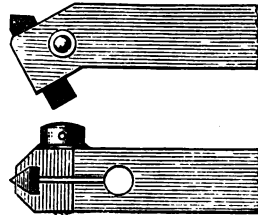


Fig. 31.—Slide-rest Cutter-bar, for straightforward tool.

A straightforward tool for general purposes is frequently made as in Fig. 31, which shows a top and side view. In this the bar is cranked down at the end, the metal is split by the saw-kerf terminating in the round hole. The cutter is of triangular section, one angle forming a point at the end of the bar. This cutter fits into a groove of corresponding section drifted through the bar at an angle with its horizontal faces, and the transverse screw, passing freely through one-half and tapped into

the other, draws the jaws together and grips the cutter firmly. In the top illustration of Fig. 31 it will be seen that the cutter has facets ground on its front faces. From this view it will also be seen that the height of the cutting edge may be adjusted by clamping the cutter at the required height, and thus obviating the necessity of gauging the height of the tool each time it is put in the slide-rest. The clamping-bolt has a washer under its head in the drawing, but this may be dispensed with if desired.

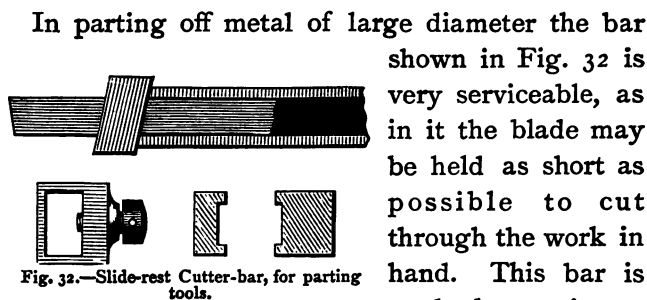


Fig. 32.—Slide-rest Cutter-bar, for parting tools.

In parting off metal of large diameter the bar shown in Fig. 32 is very serviceable, as in it the blade may be held as short as possible to cut through the work in hand. This bar is made by cutting a groove along the side of a piece of metal bar fitting the slide-rest; into this groove a strip of cast steel is fitted, and this forms the cutter. Sections of the bar in the woodcut show the form at all parts of its length, the smaller section in the centre being the extreme end reduced, as shown, to receive the strap drawn on the left. This strap is put at an angle, as shown in the upper illustration, so that the cutter-blade is supported as far under the cut as possible. The set screw and form of the strap is shown by the figure on the left, its

extreme left representing the edge, of which the face is seen in the top figure. In this cutter-bar the blades used may be of different thicknesses, according to the work to which they are applied; the width should always fit the groove accurately. The blades are ground to taper from top to bottom, so as to leave the cutting edge, that is the top, wide enough to cut a channel, in which the lower part is free. The groove in the bar is at a slight angle to keep the blade upright, and to give it a fair bearing; the strap is also shaped slightly angular at that part where the blade comes. It will be readily seen that the blade is drawn out to any desired extent, and there fixed by the set screw in the strap, and thus the length is regulated according to the depth that has to be cut. The blade itself may be tempered far more precisely than if part of a solid tool; and, moreover, the cutting edge may be left much harder than usual by tempering from the lower edge, which by being softened lends toughness and support to the hard cutting edge.

It may not be inappropriate here to point out that when a metal bar is severed by means of a parting tool in the lathe, the channel cut invariably terminates in a square flat bottom, and those who have had experience will know that in such condition the metal is comparatively difficult to break. If the channel ends in an acute angle the metal separates much easier. With this object one end of the blade may be ground to an acute point and

used to make the final cut before breaking, and so save much labour. Sharpness of the point is most important to ensure an easy break.

For internal work, when the hole being operated upon is of small size, the bar shown in Fig. 33 takes the place of a solid tool of similar outline. In that the small piece forged up from the solid to form the cutting-point soon gets ground away in the sharpening process, and the tool has to go through the fire again to be made serviceable. In the cutter-bar illustrated the bar has a portion of its length turned cylindrical to a size suited to the

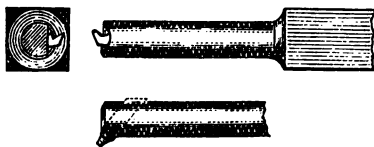


Fig. 33.—Slide-rest Cutter-bar, for inside turning.

usual requirements of such a tool. Into the end of this cylindrical part, starting from the diametrical edge, and at an angle of 45° , a hole is drilled, as shown by the dotted outline in the lower figure; this hole is made tapering and a flat facet filed on the bar at its mouth. Small pieces of cylindrical and tapering steel are fitted to it, and the ends of these are fashioned into cutters, as shown in Fig. 33, where three distinct views are given. The hole is sometimes made square by drifting and filing and the cutters of a corresponding section, but a properly fitted round cone is easier to make and answers

the purpose equally well. In grinding these cutters it is preferable to hold them in a tool made by drilling a conical hole in a bar, from which they project more than when in the cutter-bar itself; the grinding may then be done with greater ease and certainty. When a cutter is worn too short for use it is cast on one side, and a new one that costs but an inconsiderable fraction for material, and that may be made in a few minutes, is put in place of it.

Speaking generally of the four cutter-bars described, it is scarcely necessary to point out the great saving of material effected by their use; that is to say, the small cost at which the worn-out tool can be rendered as new, as compared with a similar process on the solid tool. Apart from this, each form of bar has peculiar advantages over the solid tool that it is intended to replace. Fig. 32 is, perhaps, the most obvious instance of this, but each has an advantage. Again, by making numerous cutters to these bars they are rendered equivalent to an equal number of solid tools, that is, providing only one is to be used at a time, at a very small fraction of the cost. For example, three blades fitted to the parting-tool, Fig. 32—a wide, a medium, and a narrow one—would make that tool equal in its range to three solid tools of corresponding dimensions. Small cutters of various forms adapted to particular purposes, fitted to the inside tool, Fig. 33, take the place of complete solid bars. The value of material and workmanship of

each of these would suffice for, perhaps, twenty small cutters, each of which would be equally efficacious. A direct saving in the cost of material is made by using iron for the bars in place of steel for the solid tools. In most cases good iron answers all the purposes of a cutter-bar, though occasionally it is better to use steel; that is, in cases where the material has to be reduced to small dimensions, as it would be in Fig. 33 if made to go into a hole $\frac{1}{4}$ inch in diameter.

CHAPTER XII.

OVERHEAD GEARING.

Fixed and portable—Single bands and compound gearing—Fixed bars
—Swinging bars—Revolving shafting—Screw-cutting by band-
gearing—Shape of grooves for the bands.

OVERHEAD gear designates the apparatus rigged up to drive drilling spindles, vertical cutters, and many other appliances of a similar kind. There are innumerable modifications of gearing used, and it would be impossible to give anything like an adequate description even of those commonly employed, the arrangement adopted depending so much on purely local facilities and requirements. Often a wall, ceiling, beam, or other substantial support is available for the attachment of the gear, and such a circumstance should be turned to every possible account. Those lathes which are intended to be easily movable have the overhead gear, if any, fitted to standards rising from the frame of the lathe itself, sometimes cast in one piece with the standards on which the bed rests, though more often made separately and bolted to them. Such supports are somewhat in the way, and their recommendation is the fact of their being permanent

attachments to the lathe and available for use wherever it may be. Stability necessitates comparatively bulky castings, which obscure the light and in other ways impede the workman in various operations.

Overhead gearing may be divided into two classes : one in which a single band from the fly-wheel, or other source of motion, is led over pulleys to the mandrel it has to drive ; the other in which the band from the source of motion turns a shaft from which another band, occasionally through the intervention of other shafts, goes to the object to be driven. The first method is simple, but admits of comparatively little variety in, and no accurate adjustment in the relative velocity of, the driving and driven pulleys. The second method is more elaborate, and admits of adjustments so fine that screw-cutting, with all the accuracy of a screw-cutting lathe, can be performed by its aid. The process of regulating velocities by means of bands is one that appears to have received very little attention as applied to extremely accurate speeding, but it is a subject well worthy of investigation.

The first class of overhead gear in its most simple form consists of a plain bar of rod iron, fixed paralld to and in a line vertically above the lathe centres. On the bar are fitted two pairs of pulleys, one receiving the band from the fly-wheel, the other leading the band to the cutter. The first pair of pulleys are usually fixed vertically above the

driving-wheel, whilst the second are moved along the bar to suit the position of the apparatus to be driven. The driving-band having various lengths to suit is then put in position, and the movable pulleys are finally fixed at that point where they keep the band at proper tension for working. If the band leads fairly on to the apparatus that it is to drive, or this latter is fitted with proper guide runners as described in the chapter on the Vertical Cutter Frame, the gear will work. If, however, the band leads at too great an angle it will be liable to slip off, hence the necessity of having various lengths of band. By judicious arrangement a few pieces of band suffice for all wants. First cut a length to fit the shortest workable distance, that is from the slow motion groove of the fly-wheel to the drill spindle close to the headstock; this may be about 18 to 20 feet. Then cut a length of 6 inches, another of 1 foot, another of 2 feet. With these three pieces only the band can be increased by 6, 12, 18, 24, 30, 36, or 42 inches, giving a choice of seven lengths as may be found most convenient, all within only a difference of 6 inches, which is near enough for almost anything.

Another very simple form is that of a bar jointed to a standard rising from the lathe-frame near the headstock. This bar takes two pairs of pulleys as first described, and the left-hand end has a weight attached to it to keep the band taut; this weight is increased in proportion to the work being performed. Fig. 34 illustrates such an apparatus; the

vertical bar, shown broken off at its lower end, is of wrought or cast iron. It has a collar, shown just under the lower part of the bracket, on which this rests, or the upper end is shaped pivot-like and the upper bearing of the bracket is fitted to it. The bracket itself is of cast iron having bosses bored to fit the upright loosely so that it turns freely. The projecting end of the bracket has a lug cast in with a vertical mortice hole which forms the bearing of the rod, a pin shown in the illustration being

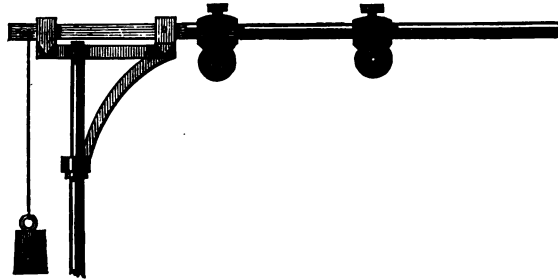


Fig. 34.—Swinging Bar overhead Gear.

the axis. The tail end of the bracket has another upright piece cast with a slot in it, in which the rod rests when weighted, as shown. This slot also forms a guide for the bar, when drawn down by the bands on the pulleys, confining its horizontal motion which is all made with the vertical bar as axis, the bracket being quite free to turn round on this.

The horizontal bar taking the two pairs of pulleys is shown round at that part where the pulleys slide. This is an advantage over a square

bar in allowing the pulleys to be canted over, which is sometimes necessary to let the band lead freely on when running at an angle. That portion to the left of the first pulleys is flattened to make it better for the bearing, and the continuation beyond the vertical slot has holes, two of which are shown, by which to suspend the weight. When easily managed it is well to make the suspension long so as to bring the weight near the ground, in which position it will be less likely to do damage in case of a breakdown. The point at which the bar is centred leaves the right-hand end heaviest, and it is advisable to put a guard on it so that it will not fall in the event of the weight being removed. A piece of wire fastened round the bracket and rod sufficiently slack to leave enough motion for working will answer this purpose, and many other ways will suggest themselves.

The swinging bar overhead gear is brought into operation by passing the driving-band round the lathe fly-wheel, bringing the two ends over the first pulleys, then over the second and round the pulley of the apparatus to be driven. The first pair of pulleys are adjusted to receive and deliver the band fairly on to the driving-wheel, the second being adjusted to perform the same functions with regard to the driller or other cutter which is to be driven. To assist in this latter adjustment the arm is swung round to come perpendicularly over the pulley, and when all is ready to start the bar

should be tilted downwards, so that the whole of the weight being on the short arm bears on the band and keeps it taut. The length of the band should be so arranged that it will when working leave the bar nearly in its normal horizontal position, though of course it must be drawn down sufficiently to lift the weight quite clear of the bottom of the back slot in the bracket. It will be obvious that this form of overhead apparatus has many advantages over the plain bar first described.

The pulleys used in both the gearings are generally made with the two wheels running side by side on the same axis. The fork in which they go being pivoted on to the cannon, which slides on the bar at right angles to it, allows the pulleys to move freely and place themselves in line with the band. It is very necessary for pulleys such as these to be free to adapt themselves to the direction in which the band runs, or this will soon be worn out by cutting against the edges. A plain pulley, such as may be bought at most ironmongery shops, if attached to a piece cord of an inch or so in length, so that it is perfectly free to move in every direction but one, will answer admirably on the apparatus just described, and is a very cheap way of fitting up overhead gear. It is, however, advisable to knock out the iron pin on which the pulley revolves, and, after carefully broaching out the hole, to fit a steel pin to form the axis.

The second form of overhead gear, in which revolving shafts are used with various bands to

transmit the motion, is shown in its most simple form in Fig. 35. The illustration represents a lathe, cut through vertically in the plane of the mandrel pulley. The bed is shown in section, surmounted by the head-stock which carries the mandrel and pulley, from one of the middle steps of which a band passes to a stepped pulley above. This pulley is on an axis which revolves between fixed centres so that its distance from the lathe pulley is unalterable. Moving on the same centres is a light frame in which is fitted, to run perfectly parallel with the first-named shaft, another shaft shown in section on the right-hand top corner of the figure. This shaft, being in a frame only free to oscillate on the same centres as the shaft driven from the mandrel, remains constantly at the same distance from it. The second revolving shaft may be raised or lowered, thereby making considerable

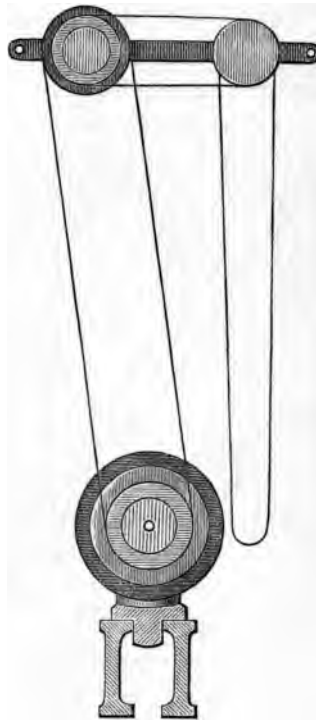


Fig. 35.—Overhead Gear, with Revolving Shafts.

alteration in the distance between it and the lathe-bed, and consequently with any apparatus fixed in the slide-rest. A grooved pulley fixed on to the leading screw of the slide running parallel with the lathe-bed, and actuated by the gearing illustrated, will traverse at a uniform rate and cut an accurate screw-thread. Of this more hereafter.

The front shaft of the gear, Fig. 35, is usually made with a parallel roller extending the whole length of the lathe-bed likely to be used with circular cutting apparatus, one end only being fitted with a stepped cone corresponding with one on the shaft driven from the mandrel. By means of this pair of stepped cones, three or four different rates of speed can be got with the single intermediary band. The plain cylindrical part will drive the band going to the cutter-frame at any point of its length, and thus all distances along the bed become equally within range. The up and down motion of the frame is sufficient to make up for any adjustment necessary through using large or small pulleys, and hence the one set of bands suffices for all purposes within the range of the pulleys. The band driving the main shaft may be led straight from the lathe fly-wheel.

Though the illustration is only intended to convey an idea of how the gear is fitted up, still the practical details can be easily filled in. The first consideration is to get rigid supports for the main shaft, on which and about the same centre the frame oscillates. Hanging standards fixed to the

ceiling or an overhead beam are perhaps the best. The frame is conveniently made of two pieces of flat bar iron, braced together with stretcher bars at each end by the holes shown in the illustration, with a locking nut on both sides, and with centred screws to form bearings for the pointed ends of the shafts. To support the front side of the frame and keep the driving-band taut it must be attached overhead, and springs of some kind or weights are very handy to keep up the required tension at all times. These and other minor details are not shown, as they are entirely dependent on local circumstances which it is quite impossible to anticipate.

Accurate speeding, for screw-cutting purposes, such as mentioned before, is arranged by using a particular groove of the mandrel pulley, and making a pulley for the main shaft of precisely the same diameter. It is not difficult to turn a wooden pulley to size so near that the difference is not perceptible in a thousand revolutions. On the main shaft a cone pulley of three or four steps is placed exactly opposite a corresponding one reversed, so that the same band serves for all speeds alike. Thus three or four varieties of speed are obtained, and each must be made accurately proportional. The band from the front shaft to the grooved disc on the slide-rest screw must come from an accurately gauged pulley, and if these two are of equal size, then the rate of thread cut will depend on the ratio of the pulleys connecting the two shafts; if these are

equal, then the thread cut will be the same rate as that of the leading screw.

Any number of pulleys may be fitted to the slide-rest screw, each to suit a special rate which by the cone pulleys already described will be available for three or four others, according to the number of steps in the cones. The pulleys for speeding with gut bands must not have the ordinary V-form of groove, but a semi-circular one exactly fitting the band. The band must have hooks and eyes that are of precisely equal diameter, or each time they pass over a pulley there will be a jerk in the speed. Grooves of V-shape jam the band and allow it to act on a smaller diameter if put on tighter; hence they cannot be depended on for speeding, even if once got to size, and this is very hard to accomplish from the difficulty in determining the diameter for callipering. Grooves turned with a round nose tool of the same radius as the band can be callipered to a nicety, and their working diameter is exactly what they calliper plus two semi-diameters of the gut band.

CHAPTER XIII.

DIVIDING APPARATUS.

Its object and use—Dividing the lathe pulley—Numbers most useful for dividing purposes—Originating and making a division plate—Drilling the holes—Index pegs of various kinds.

DIVIDING apparatus is used on the lathe for many purposes, wheel-cutting being perhaps the most important, though also the most rare. Its chief uses on the foot lathe are to space out divisions on work which is turned, such as the bolt-holes of a cylinder cover, and for marking equidistant lines on cylinders which have to be made prismatic in shape, such as bolt-heads and nuts. In conjunction with the drilling or the upright spindle and overhead gear, which are described elsewhere, the dividing apparatus is used to hold the lathe mandrel while the driller or upright cutter is used in any of their numerous applications. The apparatus consists of a division plate drilled with a series of concentric circles of equidistant holes, bored either in the face of the pulley itself or in a ring attached to it, and an index which is a point arranged to fit into the holes, and so hold the pulley from revolving.

The holes in the division plate are usually drilled

in circles of numbers which afford the largest variety of useful divisions. For general purposes the numbers best suited are 360, 200, 96, and 84, if the number of rows is limited to four. When the number of rows is not so restricted, the holes in each of course are selected to afford the largest number of extra divisions, and in deciding these it is necessary to have due regard for the purposes for which the divisions will be used. Three hundred and sixty is a very desirable number to have, as it enables the degrees of a circle to be marked, besides giving a wide range of numbers. This large number cannot well be got on a pulley of less diameter than those fitted to $5\frac{1}{2}$ -inch lathes; but for very fine work 360 holes are sometimes drilled in the pulley of a 5-inch lathe. The proportion between the size of hole and space between is about as two to one, calculating on the outside circle, which is usually the most crowded.

The pulley of a 5-inch lathe should be large enough to allow a dividing circle, say 23 inches in circumference. With 360 holes, this would give their distance apart as $\cdot 0639$ inch and the diameter of the hole, say $\cdot 0426$ inch, which is less than $\frac{1}{23}$ inch. Such small holes answer their purpose very well for fine ornamental work on ivory, &c., but will not do to hold the pulley by when taking a cut on metal. With 200 holes in the same diameter the size would be $\cdot 0766$, or $\frac{1}{13}$ inch; this is a strong hole, and if a properly fitted index is used, the pulley may

be held perfectly stiff during any of the ordinary operations. For four rows of strong holes, 200, 180, 96, and 84 will be about the most useful; this is just the same as the numbers given above with the 360 halved. The largest circle should always contain the greatest number of holes, and the distance between two rows may be enough to allow the diameter of a hole as clear space between each.

Several forms of index are in common use; some are plain springs without adjustment, and others have arrangements for vertical adjustment. In these the peg can be raised or lowered to bring any particular part of the work to correspond with certain holes in the division plate. Altering the height of the index peg will cause the pulley to revolve, and thus bring a fresh point of the work before the tool. Adjustable indexes may be used to divide a number which cannot be got on the division plate; this is done by moving the index a certain distance between each division, and thus adding to or diminishing the number of divisions as shown by the division plate. Thus, suppose it is required to cut 101 teeth in a wheel, using the 200 circle, then the division peg would be put into every alternate hole. Also at every stoppage for cutting a tooth the index itself would be moved downwards a distance equal to one-hundredth part of the distance between the two holes. By the time the entire circle was divided the peg would have been moved through a space equal to a one-hun-

dredth part of the circle, and so the divisions would be 101.

By adjusting the movable peg only once, and placing it just half-way between where the holes have been, the number of divisions will be doubled, so by this means the 180 circle may be used for dividing the degrees of a circle. For many purposes an adjustable index will be found more convenient to use than a plain one, though this latter is very useful and somewhat easier to make. The dividing apparatus which gives the greatest number of divisions is an arrangement of a worm-wheel fixed to the mandrel, with a tangent screw to actuate it. This tangent screw is adapted to take change-wheels, which will allow the screw to be turned to any extent with certainty. This form of dividing apparatus is often fitted to expensive ornamental turning lathes, but is very seldom seen on foot lathes of an ordinary kind.

A dividing apparatus may be fitted to a plain headstock without very great difficulty, and as the job is quite within the range of this treatise full details are given. The number of holes for the division plate should be decided according to requirements, and in order to see at a glance the practical value of particular numbers a table should be prepared similar to the one here given. Twelve of the most useful numbers are taken, but any others may be substituted to suit the purposes wanted.

TABLE OF DIVISIONS.

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
360	180	120	90	72	60	—	45	40	36	—	30	—	—	24	—	—	20	—	18
240	120	80	60	48	40	—	30	—	24	—	20	—	—	16	15	—	—	—	12
216	108	72	54	—	36	—	27	24	—	—	18	—	—	—	—	—	12	—	—
200	100	—	50	40	—	—	25	—	20	—	—	—	—	—	—	—	—	—	10
192	96	64	48	—	32	—	24	—	—	—	16	—	—	—	12	—	—	—	—
168	84	56	42	—	28	24	21	—	—	—	14	—	12	—	—	—	—	—	—
144	72	48	36	—	24	—	18	16	—	—	12	—	—	—	9	—	8	—	—
140	70	—	35	28	—	20	—	—	14	—	—	—	10	—	—	—	—	—	7
136	68	—	34	—	—	—	17	—	—	—	—	—	—	—	—	8	—	—	—
135	—	45	—	27	—	—	—	15	—	—	—	—	—	9	—	—	—	—	—
112	56	—	28	—	—	16	14	—	—	—	—	—	8	—	7	—	—	—	—
104	52	—	26	—	—	—	13	—	—	—	—	8	—	—	—	—	—	—	—

The top line shows the numbers up to 20, and the prime numbers, 11 and 19, are not given with either of the dividing numbers in the table, 13 is given only by 104, and 17 only by 136. If it is required to divide 11 and 19 multiplicands of these numbers must be drilled in the dividing plate. The best way to deal with these prime numbers, 11, 13, 17, and 19, if they are particularly wanted, is to drill specially for them; that is, make one row to contain 13 and 17 equal to 221, and another 11 and 19 equal to 209. As these rows will be of no practical use except for the numbers named, it is best to drill only those holes, and not the entire number; this makes the divisions clearer to read, and saves the trouble of drilling 370 holes. The way to originate these divisions is to get a circle of the number given, say 221, and, starting from a marked hole, mark every 13th hole, then re-start from the first hole and mark every 17th, and drill the holes at these marked places; thus, instead of 221, only 30 holes will be wanted. They will come at irregular intervals, and each series must be distinctively marked to avoid mistakes in use.

To originate a dividing plate it is first necessary to have a primitive circle, which is readily made of a band of metal, a small clock mainspring being, perhaps, the most convenient. The largest possible diameter should be used for this originating circle, so as to get the holes as far apart as can be, and so make any errors proportionately less. A

wooden disc is used to wrap the band on, and this, being made as large as the lathe will allow, gives the length of the band, which for a 5-inch lathe would be 30 inches if the disc was sawn carefully as circular as possible before being turned. The disc should be made of sound wood and firmly mounted on the mandrel, the face should be turned true as well as the edge, and the dividing plate which is to be drilled may be chucked direct on the disc by recessing it out in the centre and laying the plate in with its edge held by the wood.

Suppose that four rows of 200, 180, 96, and 84 respectively are to be drilled, the band to encircle the disc must first have 200 equidistant holes made in it on a length of not more than the circumference of the disc, viz. 30 inches; the holes will, therefore, be .15, or a trifle over $\frac{1}{7}$ th of an inch apart. A template for drilling the holes perfectly equidistant has to be made; this consists of two pieces of stout sheet steel, each about 2 inches long, and, for convenience, just three times the width of the band. File them up straight, and mark a central line very truly; on this central line drill two small holes at the precise distance apart that is wanted. Drill holes through the steel to rivet them together by, and break off two pieces from the metal band to put between the templates, which will have to be riveted together so as to allow the band itself to pass through freely, but without shake. A reference to the accompanying illustration will show the construction of the template (see Fig. 36). To

allow the band to pass it will be necessary to put an extra thickness of material between the plates where riveted, a piece of writing-paper being about sufficient. The two gauge holes first mentioned must be broached out carefully, quite upright and exactly the same size; they should also be made quite in a line with the centre of the aperture through which the band is to pass. The exact distance apart of these holes must be got most carefully, for the error of only $\frac{1}{100}$ th part of an inch will make a difference of 2 inches in the length of the band. The diameter of these holes



Fig. 36.—Template for making Dividing Band.

may be about $\frac{1}{10}$ inch. The steel plates should be hardened before riveting together.

The 200 holes have now to be made in the band; they are all drilled through the template. The first hole is made at about 1 inch from the end; this allows the band to go quite through the aperture. When drilled the hole is broached out through the template to the same size, and a steel pin is put through to hold the band firm. The next hole is drilled through the second hole, and is broached out to size without removing the pin till the hole is finished. Then the pin is taken out and the band passed on for the last-made hole to come under the

first hole in the template, the pin is put through, another hole is drilled, and the operations are repeated till 200 holes are made. Take a piece of metal exactly like the band and drill in it two or four equidistant holes, then cut the band half a space between the 200th hole and half a space from the 1st hole, lay it on the bench with the extra piece in the inside, and put pins through the holes next the join, so as to get the first and last hole of the band equidistant with the others. The band is then joined by soldering a strip of metal on each side of the row of holes and so kept in position. Now remove the short piece used to justify the holes with, and the band is ready to go on the disc.

Care must be taken to see that the correct number of holes, 200, are in the band, and the disc is then turned down, to allow the circle to fit on it tightly, a groove being turned in the wood so as to allow the point of the division peg to come through the band without impinging on the disc. At this stage the primitive dividing ring is ready for use on the 200 circle when the index peg has been fitted as described further on. It is here advisable to give the method of altering the ring to suit the other divisions. It is only necessary to cut the length of the band to contain the number required, and then resolder it, turn the disc down to fit the reduced diameter, and the dividing ring is again ready. Practically it is better to work differently in the case under notice, for if the band were cut off to 84 holes, the diameter of the disc would

be only a trifle over $12\frac{1}{2}$ inches, whilst by using the band with 168 holes in it and taking every second hole the same result is attained with a diameter of over 25 inches. The same reasoning applies to the 96 circle, so that the band will be best cut with 200, 192, 180, and 168 holes respectively. This will save a lot of trouble in turning

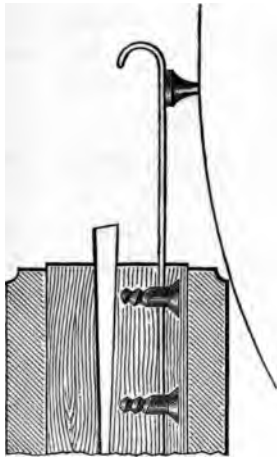


Fig. 37.—Division Peg for temporary use.

down the disc, besides affording a much better hold for the division peg, and a proportionate reduction of any errors that there may be in the originating circle. With the 192 circle, each alternate hole is used. The third row, from the outside of the plate being drilled, is bored second, and the 180 circle, though outside of it, is drilled third, in order to use the 192 circle instead of the 96.

A division peg for temporary use with the dividing band may be fitted up in the socket of the hand-rest, as shown in Fig. 37. It consists of a plain steel spring with the top end bent over hook-shaped, to afford a hold for the fingers, and a taper steel peg riveted to it. The lower end is shown wedged into the T-socket; this is shown as a specimen of an easy way in which to improvise the index. It

has been used and found to answer all the requirements.

For drilling the holes the drilling spindle, described in another chapter, is mounted on the slide-rest and driven from the overhead motion. The drill used is of peculiar shape; it cuts at the point and also on both its sides, so that it drills a conical hole tapering about 15° ; the depth may be from $\frac{1}{12}$ th to $\frac{1}{8}$ th of an inch, according to the diameter. The drill must be fitted quite tight in the drilling spindle; it must be short and stiff, so as not to bend in use. It is carefully sharpened before commencing to bore the holes, and should not be reground till the whole of them are drilled, or the shape may be altered. Every hole must be bored to precisely the same depth, and a stop must be put to the slide-rest to ensure this. If the holes are unequal in depth the divisions made with the plate cannot be accurate. The circles of holes must also run perfectly concentric with the mandrel, or the spacing will be unequal.

The holes in the division plate should be drilled, at the place where they commence, with each circle starting in a diametrical line, and the numbers should be marked by punching in the figures or otherwise. The peg which goes into the holes must be turned to a corresponding cone so as to fit; it must not reach the bottom, and the point requires to be rounded off so that it will not scratch the face of the dividing plate. When in the hole the peg ought to stand quite square and be about mid-

way up the pulley. A large sectional view of the peg in one of the holes, showing the correct proportions of the parts, is illustrated in Fig. 38. The peg is here shown apart from the index spring. It should be as short as can be conveniently used; if too short the light is kept from the point by the spring, and it is difficult to see the hole when inserting the peg.

The illustrations show three kinds of division pegs. Fig. 37 is the most simple, having no adjustment. It is a plain steel spring with the conical stalk riveted to the lower end; this stalk fits a

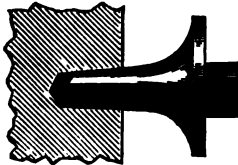


Fig. 38.—Enlarged view of Peg and Hole in Dividing Plate.



Fig. 39.—Knob for Division Peg.

hole in the spherical knob which is screwed into the side of the headstock, and allows angular motion to the peg, so that it can be put into either row of holes. The end of the spring is wrought over in a hook shape to afford a grip for the fingers; in the others a small button is riveted to the springs for that purpose. The knob screwed into the headstock is generally made like Fig. 39, and gun-metal is a suitable material. The centre of the sphere where the hole is should be so placed that the spring will stand upright when the peg is in the centre row of holes and level with the lathe centres.

The division peg illustrated in Fig. 40 has a screw fitted after the plan of the poppet headstock barrel screw, by turning which the peg may be

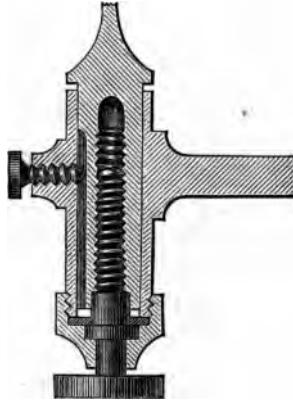


Fig. 40.—Adjustable Division Peg.

shifted to the greatest nicety. The construction is shown in the sectional drawing, and needs no further description. This is one of the best forms of adjustable division pegs.

CHAPTER XIV.

THE DRILLING SPINDLE.

Its use and how to make—Making the mandrel—Making the collars, grinding the bearings—Lead grinders—Fitting the collars, grinding the cones—Hardening and tempering—Putting together.

A DRILLING SPINDLE will be found very useful for many purposes. Apart from drilling simple holes, it may be used for grooving taps, making drifts or punches to make triangular, square, hexagonal, octagonal, and other shaped holes; also for squaring the flats of bolt-heads and shaping up prismatic pieces of all descriptions in wood or metal. On surfaces it may be used for cutting slots and grooves of all shapes; indeed to so many purposes is the drilling-spindle applied that it would scarcely be possible to enumerate them. Overhead gear and a dividing apparatus are required when using a drilling spindle. The following particulars will make its construction clear. It is not very difficult to make, and by following the drawings a serviceable tool will be produced.

Fig. 41 is a sectional drawing of the complete apparatus, in which the principles of construction may be seen at a glance. The exterior shape may

be altered to suit special circumstances, but the form shown, a plain square bar, will usually be found the most convenient for use. It is held in position on the top of the slide-rest by means of the usual tool-holder. The only reason for adopting another pattern would be when the tool-holder is of such a shape as to necessitate it, as is the case in some which have not sufficient space in the usual tool receptacle to admit the shank of the spindle.

Before constructing any piece of apparatus it is

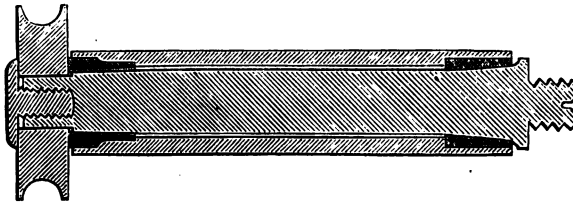


Fig. 41.—Sectional view of Drilling Spindle.

always best to make working drawings as guides during the progress of the work, then by continual reference it is easy to guard against errors, and so save much time. The size of the drilling spindle will depend for diameter on the height of the lathe-centres above the top plate of the slide-rest, and for length on the size of this same plate. A piece of square iron which will finish up to double the difference between the height of centres and top of rest, and a trifle longer than the widest way of the top plate, will be required for the shank, through which the mandrel or spindle runs. This

piece of iron must be mounted between the lathe-centres to have the ends turned true, and at the same time a very light cut may be taken along its entire length to just round off the corners ; the bar is then made quite square and flat on each side by filing. To turn the corners off of a piece of $1\frac{1}{4}$ -inch square iron would be by many considered a very difficult if not an impossible job for a light foot lathe, but it may be done without trouble if set about in a workmanlike manner. When the bar has been filed up it is well to select the truest surface for the bottom to rest on the slide-rest, and mark it so that it may be easily recognised afterwards.

The piece has to be bored through as nearly as possible central. This may be done with ordinary drills, working from both ends; the centre marks left from the turning will serve as a guide in starting. A small hole is drilled first, and larger ones subsequently, till the hole is about half the diameter of the square bar. If this hole is tolerably true centrally, and straight from end to end, it may be further enlarged by drilling, but if much out of truth the hole must be got central by using a boring bar between the lathe-centres. The square shank, being fixed in its place on the slide-rest, is traversed along the bar so that the hole is made to exactly coincide with the line of centres. The boring bar has to be just over twice the length of the hole, and, therefore, it is necessary to have it as stout as can be, so as to get the greatest pos-

sible rigidity. A bar of round cast steel will serve for the boring bar; it need only be truly centred at both ends, and must have a transverse hole at the middle of its length to take the cutter. The bar must be straight, and as large as may be to run clear of the boring. The cutter is wedged in the transverse hole to project enough to take a light cut, and the square bar fixed on the rest is traversed along it. The cutter is set out for subsequent cuts, and the boring continued till the hole in the bar is quite truly in line with the centres, and large enough for the intended spindle.

The size of the spindle to be used will depend greatly on the work to which it is to be applied. A mandrel $\frac{3}{8}$ inch in diameter will serve the purpose for light drilling, whilst for actuating cutters on metal one as large as 1 inch in diameter is used for a 5-inch lathe. To suit the requirements of this particular work the maker must select an appropriate size. Large ones have threads cut on a nose, as is illustrated in Fig. 41, and sometimes internal threads, by which chucks may be screwed to the spindle; small ones are generally made like the drill-chuck figured on page 92, Fig. 13. Small cutters, drills, &c., may be fitted into this form of spindle very firmly, but for heavy work the thread will be found necessary. The spindle runs in two collars, one at each end of the shank, which is bored out to receive them. The end-motion is confined by an abrupt cone at the nose end and the pulley bearing against the face of the back collar.

The collars must, therefore, have shoulders to prevent them being forced into the shank by the lateral pressure on the spindle.

For the mandrel select a piece of round cast steel, cut it to the correct length, anneal carefully, then centre both ends truly, and mount on the lathe to run true. Drill the hole for the screw in the tail-end, and turn the steel roughly to the correct shape. If from the working of the steel it is thought desirable it may be again thoroughly annealed at this stage. Whether the mandrel shall be hardened when finished or left perfectly soft is a question which is not readily answered. In the process of hardening the spindle is almost certain to warp, probably it will crack as well, and generally, from one or the other cause, the mandrel will be rendered useless, and all the labour spent on it wasted. A soft mandrel will answer every purpose, and may be used for an indefinite time, and for general purposes there is very little cause for troubling about hardening at all.

The two collars are made from round cast steel of the requisite diameter. Large collars are generally forged roughly to shape, but when only one or two are required it is easier to make from the solid; and for small collars, say those under 1 inch in diameter, this is always the better plan. A short length of steel is mounted in a chuck, such as the two-die chuck, Fig. 17, or the four-screw cup-chuck, Fig. 15; the end is turned flat and a small hole bored up the centre; this is


enlarged to nearly the intended size, the depth being a little more than the length of the collar; a deep groove is turned on the outside, and the rough collar can then be broken off. A second piece is prepared just in the same way, and the two blanks are thoroughly annealed before being further worked. They are then chucked, one at a time, for boring out conically; the outside should run quite true; the boring is done with an inside tool in the slide-rest. The top slide is set over, as described on page 111, to 30", this being the correct amount of taper for cone-bearings. At this angle bore out one collar to very nearly the size, as shown by the working drawing. See that the last cut is a light one, and done with a sharp tool, to leave a smooth inside to the collar, which is then taken out of the chuck and the other one bored. The front collar has its largest end turned to a bevel inside, as shown in the various woodcuts.

The two collars bored, next mount the mandrel on the lathe, and turn the parts where the bearings will come conical to correspond with the insides of the collars. Turn as smoothly as possible, and fit the collars on at some distance from their ultimate places. Thus the mandrel answers the purpose of an arbor for turning the outsides of the collars on, which is the next operation, the collars being turned to shape on the outside and made nearly small enough to go into the recessed borings in the ends of the iron shank. The ends of the collars must be turned true; they will hold on to the man-

drel tight enough to allow a fairly heavy cut to be taken, the principal care being required to guard against cutting the mandrel when turning the ends of the collars; these are next carefully annealed, so that the thick parts are made quite red-hot without burning the thin.

The next process will be to grind out the collars. Lead grinders will answer all the purposes, though brass or gun-metal ones are sometimes used. The lead grinders are made in this way:—Prepare a piece of round or square iron rod three or four inches long by centring the ends and tinning with pewter solder a part near the end. Roll up very smoothly a cylinder of writing-paper, tying a piece of string round to prevent its unrolling. Stand this cylinder on a metal surface, with the tinned part of the rod in its centre, pour in some melted lead, which will melt the pewter and solder itself to the iron rod. Mount the rod between the centres, and turn the lead to fit the largest collar, carefully keeping it to the same cone.

The collar must be driven into a chuck so that it will be quite true. The grinding is then done by supplying the lead grinder freely with rather coarse emery and oil; the emery imbeds itself in the soft metal, and soon grinds the steel smooth. An ordinary carrier is screwed on to the tail end of the grinder by which to hold it. Whilst the lathe is revolving the grinder is continually drawn to and fro, so that rings will not be cut in the collar. In this way the collar will be made very smooth,



though possibly it may be necessary to recast the lead, so as to turn the grinder to size afresh when it has been used for some time. Emery will produce a sufficiently fine surface in the collar; that on the grinder will become finer as it is used, so that it is only necessary to refrain from putting fresh emery in order to get the requisite fineness. The back collar must be ground out in the same way, and both are then cleaned to remove all the abraded particles.

When the collars are now put on the mandrel they will, of course, go further on the cone than before being ground out, but the cone will have to be reduced to allow them to come very nearly to the place they will ultimately occupy; a very fine flat file will be found very useful for this purpose. The collars are finally fitted by grinding on the mandrel itself with oilstone dust and oil, still leaving a trifle for fitting when the collars are driven into the shank. The oilstone dust is cleaned off and the collars finally turned to fit the shank. The small holes through which the oil to lubricate the bearings is supplied have to be drilled in the collars so that they will coincide with holes drilled for the same purpose in the iron shank. The inside of the collars must have a small groove leading from the oil holes to distribute the oil along the bearing. These channels must be cut with a round file; if with an angular one the collars will most likely split in hardening.

Considerable attention must be paid to the

hardening of these collars, or they will be burned in some parts whilst not hot enough in others. When red hot plunge into cold water, and they will not crack if the previous annealing process is done properly, and there are no sharp angular nicks in them. There is hardly any necessity to temper the collars; anyhow, they should be heated only sufficiently to just show a change of colour. The back end of the smaller collar, which takes the bearing of the pulley, must be made quite flat by grinding. A sheet of emery paper laid on a flat surface will do this.

To get the collars into the shank they are put in the right position for the oil holes to come uppermost and correspond with holes drilled through the iron. Drive them in slightly with a mallet, then put a bolt through the two collars, screw on the nut to draw them together. See that the head and nut of the bolt bed fair and that it pulls straight, then screw up. If the collars are very tight and do not go by this means, drive them with a heavy hammer, giving only light blows, and keeping the pressure on the bolt; by these means the two collars will be got into their places right home to the shoulder.

With the collars driven fast into the shank, the next process is to grind in the mandrel-bearings. The soft spindle is reduced by filing with a fine file, whilst it is revolved quickly in the lathe, till the bearings nearly reach the intended point. The mandrel is then taken from the lathe-centres and ground in by hand, using oilstone dust and oil for *the abrading material*. The insides of the collars

will be ground quite bright, and the spindle will become a dull lead-colour when the bearings are ground right home, so that the front cone touches the face of the front collar. The spindle, collars, and the entire shank must be thoroughly cleaned to remove all trace of the grinding material. The tail end of the spindle, which projects from the back collar, will have to be turned down to receive the pulley, which coming up to form the back-bearing, prevents endshake. The pulley is to be made as large as possible to clear the slide-rest. It can be of cast iron, and is bored slightly smaller than the size of the tail of the spindle, which is then fitted to go in tight. The pulley may be turned up true, and the gut-groove made in it when driven tight on to the spindle; but the final fit of the pulley should not be quite so tight as that, because the screw which goes into the tail is intended to force the pulley against the shoulder, which it cannot do if the fitting is very tight. The hole is tapped, and a screw fitted having a head of greater diameter than the tail of the mandrel. The pulley projects slightly beyond the end, and on screwing in the screw forces it against the shoulder on the spindle, and so holds it firm. It will be understood that the face of the pulley against the shoulder forms the bearing to prevent the endshake. There is not any appreciable wear here, as the action of nearly all the tools used in the drilling spindle is to press it backwards against the front cone.

The nose-end may next be finished; it can have

a thread cut upon it as shown in Fig. 41, or may be drilled up like the chuck, Fig. 13. It is rather difficult to cut such a short thread true and parallel with dies, so it ought to be cut in a screw-cutting lathe. The thread ought to be cut right up to the shoulder, and the remarks already made relative to the nose of the lathe-mandrel, page 27, are equally applicable to this one. To get the thread right up to the shoulder, it is necessary, whether cutting it with dies or a tool in the lathe, to nick in the termination of the thread as soon as the point where it ends is apparent. A crossing file is the best to use for this purpose, and the nicking in should be done progressively, to keep pace with the screw-cutting. With a nick cut in, the last shaving or chip of metal cut out of the screw-thread breaks off; but it does not do so in the ordinary way; consequently the metal accumulates, and the thread is cut shorter at each trip of the screw-cutter.

In describing the way in which to make a drilling spindle numerous practical processes have to be explained in detail, and it will be easy for the intelligent reader to apply them to purposes for which they are suited as occasion may require. As an example, lead grinders are used for grinding out fittings of all kinds, and the description of their make and use, as specially applied to grinding out the conical collars of the drilling spindle, will serve equally well in innumerable other cases.

CHAPTER XV.

VERTICAL CUTTER-FRAME.

Its use and construction—Circular-cutters for wheel teeth—Cutters for general purposes—Fly-cutters—Making the frame and spindle.

A CUTTER-FRAME, in which the spindle revolves vertically instead of horizontally as in the drilling spindle already described, is used for many purposes where the latter cannot be employed; as for cutting longitudinal grooves and slots, the sectional form of which is such as can be easily shaped by means of circular cutters having their edges turned to a counterpart shape and teeth formed on them, to cut the material being wrought. These circular cutters may be home-made, and for peculiar forms it is often necessary for the workman to make a special cutter. Unless sufficient quantities are used to warrant the fitting up of special apparatus for their manufacture, these home-made cutters will not as a rule be found anything like equal to those sold at the tool-shops, and which are manufactured in large quantities by the aid of specially designed machinery.

The apparatus illustrated in this chapter may be

used for wheel-cutting. It is scarcely necessary to say that the cutters required for removing the material from the interspaces of the wheel-teeth are to be bought in all shapes and sizes, suited for small work, at the tool shops, such cutters being made by templates to cut the correct epicycloidal form of tooth. A very large number of cutters would be necessary to correctly form the teeth of wheels varying in size; that is to say, each diameter of wheel should be cut with a cutter formed slightly differently, though the teeth would be ostensibly the same. Practically, however, the difference in the form is so slight that in the most accurate sets eight cutters are considered sufficient to cut from pinions of twelve leaves to wheels of infinite radius, as typified by a rack; and not unusually four cutters serve all the purposes.

For general purposes cutters having square and circular edges are most generally in request; the former, as the most easily made, being very similar to circular saws, though usually much thicker, and always having coarser teeth. Cutters of an inch to an inch and a half diameter should have about twelve to eighteen teeth; that will make them about a quarter of an inch apart. They may then be ground when blunted, and, moreover, the coarse teeth will not become clogged with shavings as do the fine teeth. For cutters that are not likely to see much service three or four teeth will answer, and are easier to form than a larger number. The single tooth or fly-cutter, however, is

still less trouble to make, and when sufficiently durable is generally used. Square-edged cutters of various thicknesses are useful for cutting out rectangular grooves, though a properly formed drill in the drilling spindle will do the same work often quite as well and in some cases better, Circular-edged cutters are used for grooving taps and cutting channels of semi-circular section, the diameter of which is equal to the thickness of the cutter employed. The grooves in taps are made to remove one-half of the thread, measuring circumferentially, so that for three grooves the width of the cutter should be just a semi-diameter of the tap. Four or six cutters of different widths will suffice for grooving all taps ranging from a quarter to three-quarters of an inch diameter. The larger sizes will absorb all the power that can be brought to bear on them in a cutter-frame of the kind here described, so that the range of work is somewhat limited.

Fly-cutters are single cutters fitted to the cross mortice hole with one projecting end shaped to the requisite form. Small brass wheels such as are used in English clocks have the teeth cut by means of a single-tooth fly-cutter, so that their effectiveness is proved. In consequence of the ease with which they can be made, fly-cutters are used for innumerable jobs requiring a cutter of special form, such as moulding, &c. It is only necessary to fit a piece of steel to the mortice hole in the spindle, leave one end projecting, file it up to the

desired shape, leaving plenty of clearance, harden and temper, and the cutter is ready for work. The cutting edges should be made as smooth as possible if a smooth finished cut is desired, and the bulk of the material should be removed by circular cutters before applying the fly. These are driven at great speed, and practically it is not possible to drive fly-cutters too fast. With quick speed and slow feed the work that can be done with a fly is almost incredible.

The accompanying illustrations show a very good form of cutter-frame. The main part to which the fittings are attached may be a gun-metal casting or forged of iron. It is essential that it should be rigid, so as to withstand the vibration caused by quick speed; this is liable to throw a fragile instrument into a state of tremor, in which condition it is impossible to produce good work. In working with quick-speed cutters, subject to vibration, it is often easy to place a stay from some substantial point to support the most unstable part of the work, and this gives surprising additional power. For example, by placing a wooden stay from the back part of the lathe-bench to catch the head of the top centre screw in this cutter-frame, the entire slide-rest and apparatus will be made inconceivably more rigid.

The top view, Fig. 42, shows a small portion of the shank part by which the apparatus is held in the slide-rest. It is only necessary to point out that when designing the pattern for the frame, the

shank must be placed at the correct height to bring the mortice groove in the spindle on a level with the lathe-centres. The shank may be of square section, about $\frac{3}{4}$ inch for a 5-inch centre lathe, the width of the frame part corresponding as seen by the front view, Fig. 43. The arms that project to take the centre screws may be shaped off to fancy as shown in Fig. 42. A frame made to

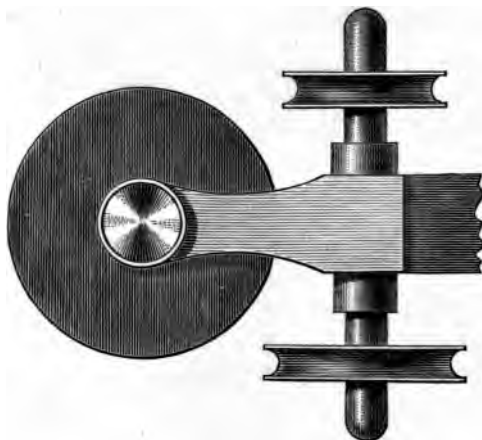


Fig. 42.—Top view of Vertical Cutter Frame.

the proportions given in the illustration will be found to be sufficiently strong without being clumsy for all the purposes to which it is likely to be applied. The upright spindle must run truly vertical to produce accurate work; if slanting, the cutters revolving in it will not cut grooves precisely corresponding with their edges. In use the cutters are often made to serve a purpose to which they

are not really adapted by tilting the frame slightly.

The cutter-spindle is seen in Fig. 43. It is made of steel, and has a large-sized pulley fitted to it, to

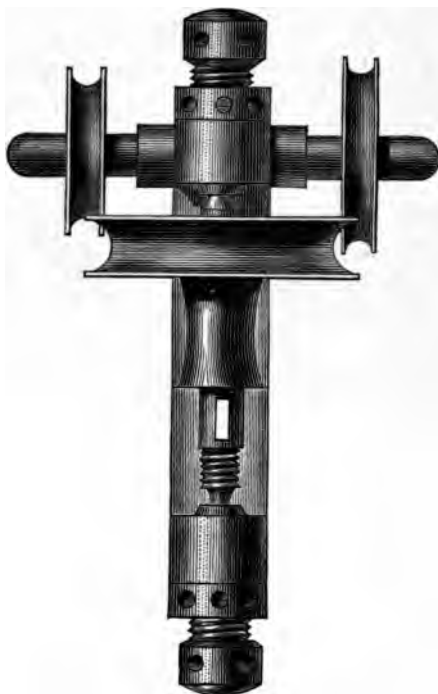


Fig. 43.—Front view of Vertical Cutter-Frame.

be driven from the overhead gear. This pulley must have a wide groove for the band which has to pass entirely round it, so that half of its diameter is encircled by two breadths of band. For this reason the two guide pulleys, or runners, are of different

sizes, so that the driving band is led on and taken off at different heights, the difference being the thickness of the band used, and thus the band is prevented from over riding, as it probably would do if the guide pulleys were of equal size. Precisely the same effect is produced by using runners of equal diameter and placing the pins on which they revolve at different heights. These runners must have wide semicircular grooves, so as to receive the band fairly when running at an angle. Narrow grooves will wear out the band by cutting with their edges, and angular grooves will absorb power detrimentally by jamming. Pulleys which are to be driven by a single band require to be grooved out angularly, but those serving merely as runners are best made with wide semicircular grooves in which the band runs as freely as possible.

The spindle has pointed ends, as should all revolving arbors in preference to centred ends, which owing to the usual flatness of the end drive the oil from the actual point of friction by centrifugal force. It is necessary to see that the top bearing is lubricated when working, as the oil applied to it is apt to run down the cone point away from the screw end. The lower bearing is of course arranged to the best advantage; but if the upper end of the spindle were centred like the bottom screw, and thus offered a receptacle for the oil, it would be driven off by centrifugal force as explained above. Though apparently a very trivial matter, yet practically proper arrange-

ments for lubrication are of primary consideration.

The form of the spindle is of little moment so long as strength is not sacrificed. The shoulder against which cutters are jambed by the nuts should be broad and flat. The thread for the locking nut being as fine as may be consistent with strength, the diameter being but the merest shade less than that of the plain part on which the cutters should fit. In Fig. 44 the locking nut is shown in plan and section; a hexagonal nut is used in preference



Fig. 44.—Locking Nut of Vertical Cutter-frame.

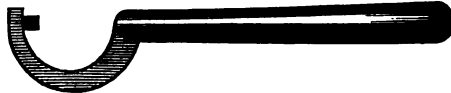


Fig. 45.—Hooked Tommy.

to a circular one with holes drilled radially, such as those shown as lock-nuts on the screws forming the bearings, as it is more easy to clamp in the vice for tightening, though the other form will answer all the purposes. To actuate these nuts, which have but comparatively shallow holes, a "tommy" of the ordinary form will not do, and one of special shape, illustrated in Fig. 45, and called a "hooked tommy" has to be provided. This tool has simply to be bent to the curve, and then filed out to accurately fit the half circumference of the nut; the small pin at the end of the hook is then inserted. In use the hooked tommy

must always be turned in the direction of the curve, and of course is available for screwing up or unscrewing by simply turning it over to the side required. Hooked tommys are employed to actuate all those capstan headed screws and nuts which from insufficiency in the depth of the holes do not afford a hold for the ordinary straightforward tommy.

The stud-pins on which the runners revolve are of round steel, being screwed into the frame. The runners are shown loose, that is free to drop off; but a pin may be put diametrically through each stud near the ends to prevent such an occurrence. The runners must, however, have plenty of freedom along the pins, so that they may adjust themselves to positions suited to the angles at which the driving-band is led on and off of the overhead



Fig. 46.—Screw Collet of Vertical Cutter-frame.

gear. If quite free and made with wide open grooves, the runners will lead a band at almost any angle in reason, and so obviate a lot of trouble in making several lengths of band to suit particular positions of the vertical cutter-frame along the lathe-bed.

The cross mortice hole in the spindle is useful for single-tooth cutters as previously described. These are fitted to the opening and are held by a set screw from the side. The substance of the spindle itself is not enough to afford a hold for the set screw, and the collet shown in Fig. 46, which gives end and sectional views, has to be used. The mortice hole in this collet should be slightly less

than the corresponding mortice through the spindle in all its dimensions; so that the cutters fitted to it will pass free in the spindle hole. The set screw, which is tapped in the collet, must pass clear through the spindle; this will necessitate boring a hole to the size of the diameter of the thread in the spindle. In use the collet is fixed by the clamp-nut just as a circular cutter would be; always taking the precaution to see that the mortice holes correspond and the set screw is opposite the hole in the spindle. The head of this set screw should be as flat as may be so as to clear the work when in use. The diameter of the spindle where the cutters fit is regulated by the size of hole in the circular cutters as usually made, that is about $\frac{3}{8}$ inch. It is advisable to procure a circular cutter to fit by when making the spindle, if bought cutters are likely to be used; if home-made ones are to be solely employed, then the holes in them can be made to suit the size of the spindle whatever may be the diameter.

CHAPTER XVI.

SCREW-CUTTING BY SELF-ACTING MOTION.

Theoretical principles—Wheels usually supplied—Preparing a table of rates that can be cut—Screw-threads, how described—Rules for calculating change-wheels—Examples proving the calculation—Multiple threads.

SCREW-CUTTING is performed in lathes specially arranged for the purpose, as described in the second chapter, by self-acting feed-motion. This automatically moves the tool along in the direction of the axis of the work whilst this is revolving, and thus a spiral is cut on the cylinder, forming of it a screw. To fully understand the theoretical principles of screw-cutting in the lathe:—suppose a cylindrical rod turned true and running between the lathe-centres; a cutting-tool attached to a nut working on a screw which revolves in fixed bearings parallel to the cylinder, and properly placed for cutting, will, when the rotary motion of the cylinder is imparted to the screw, traverse longitudinally and cut a spiral groove. It is evident that if the cylinder and guide-screw make equal revolutions, the thread on the cylinder will be of the same rate or pitch as that of the screw, and if the

guide-screw and the cylinder revolve in the same direction the threads will be in the same direction, but if the rotation is in contrary directions the thread will be reversed, that is, one will be right-handed and the other left-handed. When the relative velocity of guide-screw and cylinder is varied, the ratio between the respective threads is varied in the same ratio; or when the cylinder makes two revolutions to one of the guide-screw, the thread traced will have twice the number of threads in a given length. These conditions once understood, screw-cutting by change-wheels will be no longer the mystery that it is to some.

In the ordinary screw-cutting lathe the mandrel itself has a projecting tail, as shown in Fig. 1, on which change-wheels of various sizes are put as required. The guide-screw is put in bearings inside, or just in front, of the lathe-bed, and has a projecting piece at the left-hand end precisely the same diameter as the mandrel tail, so that wheels fitting one are interchangeable. The slide-rest fitting the bed has a clamp-nut, which may be engaged and disengaged with the screw by means of a handle within easy access, and under the control of the operator. The threads that may be cut are both right and left-handed, and limited in their number only by the variety of change-wheels that are available. The relative velocity of the mandrel, and with it the work to be threaded, and the guide-screw, and with it the traverse of the cutting-tool, is regulated by putting on each wheels duly pro-

portionate to the work required. When the pitch of the leading screw is known, the production of threads of any desired ratio becomes merely a matter of calculation.

Change-wheels for heavy screw-cutting lathes, and, indeed, most of those in general use, are made of cast iron ; and are very cheap and effective. They may be bought in sets or singly of various pitches, *i.e.* number of teeth to a given diameter, suited to the size of the lathe for which they are to be used. The set usually consists of 22 wheels, including one pair, the smallest having 20 teeth, and the largest 100 or 120. Gun-metal and brass engine-cut wheels are supplied with high-class lathes made for amateurs' use ; these are from about 16 to 20 pitch, *i.e.* have about that number of teeth per inch diameter. The set generally consists of 19 wheels, including two pairs, having from 24 to 120 teeth. The difference in ratios is explained by the fact of the wheels being in one case multiples of 5 and in the other multiples of 6.

When placed in position for working, a simple train of wheels consists of three only, two of which have to be of definite proportions, the third being merely an idle wheel. One is called the "driver," that is, it conveys the motion, being fixed to the mandrel ; one is the "driven," that is, it is fixed to the guide-screw, and is driven by the mandrel-wheel. The intermediate wheel, called a "stud-wheel," is of any size convenient for connecting the driver with the driven. A compound train con-

sists in its simplest form of four wheels, and is different from the set just described only inasmuch that the stud-wheel is replaced by two wheels. These are fixed on the same axis and revolve together, one driven by the mandrel-wheel, the other driving the screw-wheel. The relative size of these two wheels form elements in the calculation, the driver becoming part of the mandrel-wheel and the driven part of the screw-wheel.

A table of the threads which may be cut on the particular lathe should be the first consideration to the possessor of a screw-cutting lathe. This must be prepared specially agreeable to the rate of the leading-screw and the wheels available, and, once made, all trouble of calculating for particular jobs is obviated. In order to avoid complication, every whole number from 1 to 100 that can be cut should be written down, and opposite to it the numbers of the wheels requisite. Pitches that may occasionally be met with involving the use of fractions are easily calculated by a glance at this table, and it is easy to see whether any number that may be required can be cut or not. In the latter case the next pitch nearest, whether coarser or finer, is seen, and whether it is sufficiently accurate for the purpose may be determined off hand.

Whether the nearest pitch will serve the purpose will depend on the purpose for which the screw is required ; for accurate work nothing short of the exact pitch should suffice. It is satisfactory to note that first-class work is now put together with

screws of a definite rate, which can be cut with the wheels usually accompanying a screw-cutting lathe. The cause of the origin of some of the threads involving such peculiar fractions is explained in another chapter. For some work the error of a few hundredths of a turn per inch is of no consequence, and is, in fact, much nearer accuracy than could be depended upon in the work produced by dies which are self-guiding.

When preparing and calculating a screw-cutting table, it must be remembered that the number of teeth in the wheels required to cut a given rate of threads is governed by the pitch of the leading-screw. The wheels themselves must, however, be considered in relation to the peculiarities of the machine on which they are to be placed, as well as to the number of their teeth; and from these reasons it is impossible to adopt one table common to all lathes having a leading screw at the same pitch.

There are various ways of describing screw-threads, *e.g.* the same thread might be said to be $\frac{1}{4}$ -inch pitch, meaning that the distance apart of the threads is $\frac{1}{4}$ inch, measuring in a straight line from one thread to a corresponding part of the next; or to have four threads or turns per inch, meaning that if the screw were turned round four complete revolutions in its nut it would have moved longitudinally the space of 1 inch; or, again, it might be termed $\cdot 25$ -inch pitch, which is the same as the first example, the fraction being

expressed in decimal parts. This explanation of the terms used will enable the uninitiated to understand what is meant when speaking of threads technically. There are almost innumerable formulæ for calculating wheels, and it is hard to decide on one of universal application, for the explanation which is perfectly clear to one mind may be incomprehensible jargon to another of equal culture.

Expressed in a simple rule-of-three sum, the calculation is this:—The pitch of the guide-screw is to the pitch of the screw to be cut as the diameter of the wheel on the mandrel is to the diameter of the wheel on the guide-screw. This rule may always be used to prove a doubtful calculation. The diameters of the wheels are, of course, most easily expressed by the number of teeth they contain. When a pair of wheels are used on the intermediate stud, then the wheel on the mandrel is multiplied by that driving on the stud, and the driven wheel has to be multiplied by the wheel on the guide-screw; thus the wheels are more correctly expressed by the terms drivers and driven.

The easiest possible rule is probably this:—Write down in the form of a vulgar fraction the number of threads in a given length of the guide-screw and the threads in the same length of the screw to be cut. Multiply both by a number that will produce a numerator and denominator equal to some two of your set of change-wheels. Put the quotient of the guide-screw on the mandrel, or as

drivers, and that of the pitch required on the guide-screw, or as driven; arranged in this way the desired result will be attained. The knowledge of arithmetic necessarily involved in the calculation is of the most elementary and simple character, and few can fail to work out the simple rule.

Examples afford the best means of showing the working, and we will suppose that calculations are required for a lathe having a guide-screw of four threads per inch, or $\frac{1}{4}$ pitch. To cut five threads per inch we calculate according to the rule last given thus:—Put down the two rates in the form of a vulgar fraction, $\frac{5}{4}$; multiplying both by a number, say 10, we get $\frac{50}{4}$; by 15, $\frac{75}{8}$; by 20, $\frac{100}{8}$. Every one of these numbers is to be found in the usual set of change-wheels, and in practice we simply select those two which are most convenient in size. In the last three, putting the 100 on the guide-screw and the 80 on the mandrel, and any wheel on the stud to form an intermediary to reverse the motion, we shall cut a right-handed thread of 5 turns to the inch. With two studs and two idle intermediary wheels the thread will be the same rate, but left-handed.

To calculate the wheels for cutting an odd pitch, as $4\frac{3}{4}$ per inch, offers no more trouble whatever when once understood. By the example we see that the first fraction consists of the number of threads in equal lengths of guide-screw and screw required. In 4 inches of the rate now required there are 19 turns, and in the same length of guide-screw

16, so we put down $\frac{1}{8}$, and multiplying by 5 get $\frac{5}{8}$, the wheels required. Suppose we want to cut $6\frac{3}{4}$ threads per inch, then we get as the first fraction $\frac{1}{16}$, which multiplied by 5 gives $\frac{5}{16}$. If there is a wheel of 135 teeth the calculation is finished, but if 120 is the largest wheel available, then we must find some means of reducing the large number. This is easily done by breaking up the fraction, as shown in the next example.

Suppose we want to cut 40 threads per inch, then the fraction stands $\frac{1}{4}$. To get the small number to equal one of the smallest of the change-wheels it must be multiplied by 10 at least, and this gives 400 as the size of the wheel wanted on the guide-screw. This number is, of course, beyond the range altogether; however, we proceed as before, and get $\frac{100}{400}$; this is equal to $\frac{80 \times 5}{20 \times 2}$. Here the first numerator and denominator are to be found amongst our wheels, and the second pair multiplied by 10 give $\frac{5}{20}$. This involves the use of two wheels of 20, and as these are not usually found we use 15 as the multiplicand, and get $\frac{75}{30}$, the complete fraction standing thus, $\frac{80}{15} - \frac{75}{30}$. In case the wheels do not gear well together it may be changed by multiplying, always remembering to serve one numerator and one denominator alike, thus by adding $\frac{1}{4}$ to the 80 and 20 we get $\frac{100}{25} - \frac{75}{30}$. With these the gearing can probably be mounted, always remembering that the products of the screw to be cut, viz. 100 and 75, represent the driven wheels; and putting one of these on the guide-screw, and one of the

products of the guide-screw on the mandrel, the other two are put on the stud, one driving the guide-screw, the other driven from the mandrel. In the same way several studs with compound wheels may be introduced, and thus the capacity of screw-cutting gear extended.

To prove whether a calculation is correct, the most simple plan is to multiply all the driving wheels together and all the driven wheels together, divide the greater number by the less, and the quotient will show the ratio between the guide-screw and the screw to be cut. As example, take the last calculation, $100 \times 75 = 7500$, and $30 \times 25 = 750$, then dividing 7500 by 750 the product is 10, and the ratio between the guide-screw and the one to be cut is as 40 : 4, hence the accuracy of the wheels is proved.

Double, triple, quadruple, and multiple threads generally may be cut on the lathe, the slide-rest being made to traverse along the bed at the correct speed representing the pitch. If a single point is used for cutting the thread the several different ones are made equidistant by so arranging the train of wheels that the one on the mandrel contains an exact multiple of the number of threads. This wheel is marked at equidistant parts, say on the teeth, and one space in the wheel that it drives is also marked, chalk serving all ordinary purposes if care is exercised to avoid rubbing it off. When one thread has been fully cut out the mandrel wheel is employed as a division plate to start

the next equidistant from the first. A comb-screw tool may be used having the teeth in it to correspond with the several threads taken collectively; thus, with a comb-tool cutting 10 threads per inch and the slide-rest travelling at the rate of 5 per inch a double screw of 5 pitch will be cut at one operation.

Square, angular, and any form of screws may be cut both inside and outside with the screw-cutting motion, it being only necessary to form the point of the tool to cut the shape required. Single points will answer most purposes, and are always to be preferred for removing the bulk of the material, the comb-chasers serving to smooth and finish the thread.

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